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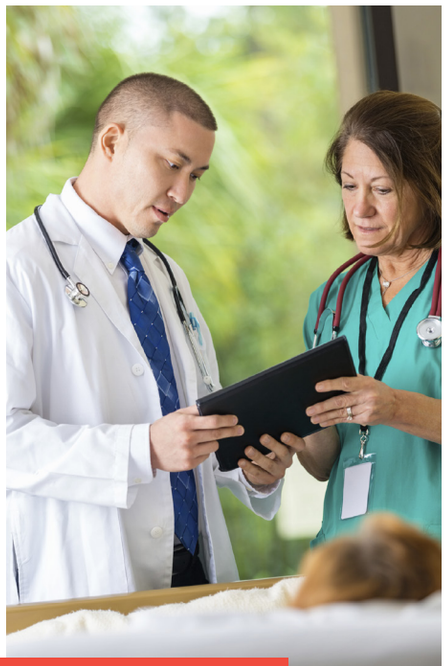
- Health characteristics and self-identified health promotion needs of Army personnel in Perth Western Australia
- Effects of Penthrox® (methoxyflurane) as an analgesic on Cardiovascular and respiratory functions in the pre-hospital setting
- Aligning Defence Environmental and Occupational Health (EOH) Capability with Future Requirements: The 4th Australian Defence Force EOH Conference

The Journal of the Australasian Military Medicine Association



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Cover photo courtesy of the Australian Government Department of Defence

Caption: Thumbs up, Corporal Garry Francis, a medic with the First Mentoring Task Force gives the all clear to a local child after providing some first aid.

Journal of Military and Veterans' Health

Australasian Military Medicine Association

STATEMENT OF OBJECTIVES

The Australasian Military Medicine Association is an independent, professional scientific organisation of health professionals with the objectives of:

- Promoting the study of military medicine
- Bringing together those with an interest in military medicine
- Disseminating knowledge of military medicine
- Publishing and distributing a journal in military medicine
- Promoting research in military medicine

Membership of the Association is open to doctors, dentists, nurses, pharmacists, paramedics and anyone with a professional interest in any of the disciplines of military medicine. The Association is totally independent of the Australian Defence Force.

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113 Harrington Street
Hobart Tas 7000
Australia
Ph: +61 3 62347844
Email: editorial@jmvh.org

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Editorial

The major Naval battle of World War 1 occurred between the Royal Navy's Grand Fleet and the Imperial German Navy's High Seas Fleet from 31 May to 1 June 1916 near the Jutland Peninsula in Denmark. The Germany intention was to trap and destroy a portion of the Grand Fleet, so as to break the British blockade of German shipping. Fourteen British and eleven German ships were sunk, with the British losing more ships and twice as many sailors. While both sides claimed victory, it was not decisive for either side and there was to be no further such battles for the remainder of the war. One of the Royal Navy ships, HMS Shark, an Acasta-class destroyer built in 1912, was sunk by torpedo after being crippled by gunfire during an unsuccessful torpedo attack on the evening of 31 May 1916. Amongst those killed was Surgeon Probationer Robert Walker, a 4th year medical student at Edinburgh University, who had joined the Royal Navy Volunteer Reserve (RNVR) and was assigned to HMS Shark in August 1915. At the time, due to a serious shortage of naval doctors, third- and fourth-year medical students were enrolled into the Navy as Surgeon Probationers (Surgeon Sub-Lieutenants), given some further practical training and then dispatched around the Fleet. He was last seen tending a wounded sailor who had lost his hand when there was another blast. He was not seen again but was thought to have been killed. Surgeon Probationer Walker had been born in Fremantle, WA in 1893 and was one of the 8 Australians listed as killed in the Battle of Jutland. While there is little further information readily available, the loss of an Australian medical student 100 years ago highlights the challenges facing the Navy at the time.

On a more modern note, Dr Mohamed Khadra, a Sydney surgeon, has recently published his latest book entitled 'Honour, Duty, Courage'. Whilst ostensibly written as a novel, it is based on numerous interviews with Australian military doctors and nurses, which has allowed him to dramatise events that have occurred over a range of conflicts whilst maintaining confidentiality. The fictional format has also allowed him to explore some of the ethical and moral challenges facing military health practitioners, while acknowledging the impacts such challenges invariably have on those involved. This is a useful and unique addition to the military medical literature.

Our second issue has a range of interesting articles, with excellent articles on Army health promotion needs, the effects of methoxyflurane as an analgesic on cardiovascular and respiratory functions, the second part of the pioneers of Australian military malariology series, Defence environmental and occupational health, and the use of art therapy in PTSD. Finally, there are two reprints, which look at anaesthetic use during the Pearl Harbour attacks and medical sustainability in expeditionary sea-based operations, which is very timely with the commissioning of HMAS Canberra and HMAS Adelaide.

We continue to get a good range of articles, but other military and veterans' health articles are always very welcome and we would encourage all our readers to consider writing on their areas of military or veterans' health interest. Our themes are now available for both 2016 and 2017 to allow for authors to research and develop their articles – we certainly welcome articles in these areas but welcome any articles across the broader spectrum of military health.

Dr Andy Robertson, CSC, PSM
Commodore, RANR
Editor-in-Chief

1 Khadra M. Honour, duty, courage. Penguin Random House Australia; Sydney:2015.

Health characteristics and self-identified health promotion needs of Army personnel in Perth Western Australia

S. Batt[1], P. Geerlings[2], C. Fetherston[1]

Introduction

Australian Defence Force (ADF) personnel require high levels of health and fitness to cope with the inherently stressful situations that occur as part of military life. However, several health and lifestyle issues among ADF personnel have been identified relating to mental health and alcohol use[1], tobacco smoking in deployed personnel[2] and increased body mass index (BMI).[3] Mental disorders among service personnel have been of increasing concern,[1,4] and recent recognition of issues around alcohol use has led to a focus for ADF culture change.[5,6] While cardiovascular risk factors such as smoking have long been associated with the military, and ongoing efforts to reduce smoking are required,[2,7] overweight and obesity have become more prevalent[8,9] and costly[10] in recent years. This is despite such diseases historically being reported at lower rates than in civilian populations, probably due to a 'healthy worker effect'.[3] This effect has been attributed to ADF applicant screening processes whereby individuals with specified health problems are declined entry, resulting in a healthier workforce.[3] It has been suggested the increasing prevalence of overweight and obesity among service personnel may in part be related to changes made to ADF entry restrictions in 2005, which allow acceptance of applicants with a BMI of up to 33kg/m2, in the absence of hypertension, elevated blood cholesterol, or evidence of cardiovascular or other metabolic disease.[3,10] At local levels, an important step in addressing many of these identified health risk factors is collaboration with personnel and identification of their health promotion needs.

This preliminary study sought to identify baseline cardiovascular and mental health characteristics of a cohort of Army personnel in Perth Western Australia, along with their self-identified needs related to health promotion activities, with a view to guiding future workplace health promotion initiatives. Through the application of needs assessment principles, stakeholder voices were incorporated to identify direction in program planning,[11] and to foster the community ownership and action required for successful health promotion.[12] In this study, the workplace provides an opportune setting, and engagement with the target group early in the health promotion evaluation cycle can encourage empowerment, self-help, social support and participation, which are essential requirements for health behaviour change.[13]

Materials and Methods

Study design and participants

This descriptive study used a cross sectional survey designed to collect anthropometric and self-reported data concerning health behaviours, risk factors and health related interests among personnel serving in an Australian Army Brigade between July 2011 and July 2012. The Brigade consisted of actively serving armoured, infantry, artillery, engineering, signals, logistic, and headquarters personnel who had completed initial military training, were located within one Perth barracks, and were on duty at the time of data collection. Potential participants included 83 full-time (FT) and 385 part-time (PT) personnel who were recruited by the principal researcher during one information session. No enticements or incentives were provided and potential participants were advised that participation was voluntary and they were free to leave the study at any stage. The study was delimited to Brigade personnel who expressed interest in participating, and who were provided with an information and consent form, questionnaire to be completed anonymously, and contact information for mental health support. Ethics approval was granted by the Curtin University Human Research Ethics Committee and the Australian Defence Human Research Ethics Committee.

Instrument

A questionnaire was developed using validated surveys which included the 2007 National Drug Strategy Household Survey,[14] World Health Organization's Alcohol Use Disorders Identification Test,[15] Brief Lifestyle and Mood Assessment Tool,[16]

and Brief Physical Activity Assessment tool.[17] In addition to this, face validity was confirmed through questionnaire review by military health personnel. The final survey included 15 questions designed to collect categorical data on health behaviours, health promotion interests, and the desire to participate in workplace health promotion. Each health behaviour item was accompanied by a 'readiness to change' question that asked respondents if they felt a need to change their health behaviour, if they wanted help to make a change, and when they wanted help; either now or in the future. Participants also provided demographic data including gender, age, service type, rank, and education level.

Measures

Anthropometric and clinical measurements were collected by the principal researcher at the time of survey completion and included height, weight, BMI, waist circumference (WC), resting radial pulse rate (PR), and blood pressure (BP). All respondents were provided with a copy of their clinical measurements, and those with measurements that fell within ranges of increased-risk were referred to their General Practitioner. Height was measured to the nearest mm using a stadiometer with the participant standing bare foot and their head positioned in the horizontal plane. Weight was measured to the nearest 100g using a new Soehnle digital scale[18,19] with the participant wearing standard issue uniform pants and shirt, and no shoes. Weight of the uniform ranged from 1.9 to 2.1kg according to size and was subtracted from the observed reading to obtain a final weight. WC was measured to the nearest 5mm with the participant standing upright, using a flexible tape measure positioned flat against the skin at the level midway between the lowest rib margin and iliac crest, roughly in line with the umbilicus.[20] Resting PR was measured with the participant in a seated position, by palpating the radial pulse, and where the pulse was noted to be regular, counting for 60 seconds. No irregular pulse rates were identified. BP was measured using a calibrated and regularly maintained MAC aneroid sphygmomanometer, which has been found to be reliable and accurate.[21] BP was obtained according to the Heart Foundation guidelines for measuring BP and validation of BP measurement devices.[22] BP and PR were measured after the participant had been sitting comfortably for five minutes, and had not consumed caffeine, participated in physical activity or smoked in the 30 minutes prior. For the purpose of the study, each participant's blood pressure was only measured once and was rounded to the nearest 5mmHg. Intra-test reliability for the single researcher collecting data on each measurement was determined by comparing two recordings taken in each position within approximately five minutes of each other. In the case of BP measurement, the cuff was removed and then re-applied at the same position before the next measurement was taken. A series of dual measurements were undertaken with 10 participants. Intra class correlations for the 10 individuals were 1.0 for height and weight, 0.998 for PR and BP, and 0.993 for WC.

Data Analysis

Descriptive categorical data, including demographic characteristics, health behaviours, anthropometric measurements and perceptions regarding health promotion opportunities were analysed using frequencies and percentages. Tests of association were conducted only to determine target group and focus areas for health promotion within the cohort studied, rather than to generalise to the greater military population. All variables of interest were categorised and Pearson's chi-square test was used to analyse two-way associations among cardiovascular, mental health, and demographic variables. Hierarchical log-linear regression analysis was used to determine there were no significant higher order interactions.[23,24] Odds ratios are reported only as an indication of the strength of reported associations and should be interpreted with caution where variables of interest are common.[25] Analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 19® for windows[26] and p values <.05 were considered significant. Categories measuring parameters of BP, PR, WC and BMI were created according to accepted reference ranges. Reference ranges used to interpret PR were: 60-100 beats per minute (bpm) (normal)[27]; BP: <120/80mmHg (normal), 120-139/80-89mmHg (high normal), 140–59/90-99mmHg (mild hypertensive);[22] BMI: <18.5kg/m2 (underweight), 18.5-24.9kg/m2 (healthy weight), 25.0-29.9kg/m2 (overweight), >30.0kg/m2 (obese);[28] and WC: >94cm for men, >80cm for women (increased risk).[28] The Australian guideline of no more than two standard drinks on any day to reduce lifetime risk of alcohol related harm[29] was used to determine alcohol consumption at levels of increased risk.

Results

The participation rate amongst FT and PT personnel was 53.7% (n=44) and 58.7% (n=266) respectively. Two hundred and thirty eight respondents (88.1%) were male, 32 (11.9%) were female, 48 (17.8%) were Commissioned Officers and 220 (81.5%) held ranks of Private to Warrant Officer. Eighty six respondents (31.9%) were aged from 18-25 years, 76 (28.1%) from 26-35 years, 57 (21.1%) from 36-45

years, and 51 (18.9%) were aged 46 years and over. Approximately equal numbers of secondary school (n=90, 33.3%), trade/diploma (n=84, 31.1%), and university qualification (n=94, 34.8%) were identified as the highest level of education completed. Rates of university education were higher in PT (n=87, 38.8%) than FT (n=7, 15.9%) respondents.

Most respondents (n=269, 99.6%) had a resting PR in the normal range, almost half (n=133, 49.3%) had a BP in the high normal range, and 18.1% (n=49) had a BP in the mild hypertensive range. Just over half (n=153, 56.6%) had a BMI in the overweight or obese range, and one third (n=97, 35.9%) had a WC of increased risk. The majority of respondents (n=195, 72.2%) reported participation in at least 30 minutes of moderate physical activity five or more times per week, and were non-smokers (n=224, 83%). The prevalence of smoking was higher in FT (n=14, 31.8%) than PT (n=32, 14.2%) respondents. Only 28 respondents (10.4%) consumed at least two servings of fruit and five servings of vegetables daily. Table 1 shows significant associations between covariates and BMI, WC and smoking. There was no significant association between smoking and gender (women n=5, 15.6%; men n=41, 17.2%).

More than half the study sample (n=147, 54.4%)

Table 1. Significant associations between covariates and BMI, WC, smoking, mental health, stress and alcohol consumption.

	n(%)	Chi square	p value	Odds Ratio (95%CI)
	BMI >25 kg/m2			
Sex (Male)	141(59.2)	x2(1)=5.431	<.05	2.42(1.14-5.19)
Age >35 years	88(81.5)	x2(1)=45.138	<.001	6.57(3.68-11.71)
BP >139/89 mmHg	40(81.6)	x2(1)=15.196	<.001	4.25(1.97-9.17)
WC >94 cm (male) / >80 cm (female)	95(97.9)	x2(1)=105.012	<.001	94.18(22.41-395.75)*
	WC >94 cm (male) / >80 cm (female)			
Age >35 years	70(64.8)	x2(1)=65.26	<.001	9.21(5.20-16.31)
BP >139/89 mmHg	29(59.2)	x2 (1)=14.067	<.001	3.26(1.72-6.17)
	Smoking <daily			
Service Type (FT)	14(31.8)	x2 (1)=8.125	<.01	2.83(1.35-5.91)
Highest Education (School/Trade)	36(20.7)	x2 (1)=4.337	<.05	2.19(1.03-4.65)
	Mental Health Concern			
Service Type (FT)	18(40.9)	x2(1)=6.898	<.05	2.44(1.24-4.80)
	Stress			
Mental Health Concern	64(94.1)	x2(1)=57.679	<.001	22.94(8.04-65.44)*
	3 or More Standard Drinks of Alcohol			
Age 18-35 years	104(68.9)	x2(1)=28.484	<.001	4.12(2.42-7.01)
WC <94 cm (male) or <80 cm (female)	98(60.5)	x2(1)=5.225	<.05	1.82(1.09-3.06)
Physical Activity >5 x 30 mins/week	114(62.3)	x2(1)=13.631	<.001	2.86(1.62-5.05)
Stress	87(61.3)	x2(1)=4.923	<.05	1.76(1.07-2.91)

*common

reported stress from one or more sources was adversely impacting their daily life and activities. The most frequently identified sources of stress were work (n=73, 27%), relationships (n=44, 16.3%), and money (n=42, 15.6%). One quarter (n=68, 25.2%) of the sample, and more FT (n=18, 40.9%) than PT (n=50, 22.1%) respondents had experienced a mental health concern *(felt down, depressed, hopeless; been bothered by having little interest or pleasure in doing things; or worrying a lot about everyday problems)* in the past month. The majority of respondents consumed alcohol (n=256, 94.8%), with the most frequent consumption being 2-3 days per week (n=92, 34.1%). Just over half the respondents reported drinking alcohol at levels of increased risk, with 51.9% (n=140) consuming three or more standard drinks, and 20% (n=54) consuming five or more standard drinks on a typical day. Table 1 shows significant associations between covariates and mental health, stress and alcohol consumption. There was no significant association between alcohol use at levels of increased risk and gender (women n=12, 38.7%; men n=128, 57.4%).

Table 2 shows the self-identified need of respondents to improve their health and/or change their lifestyle behaviours, and their desire for help to achieve this. Almost three quarters of respondents (n=197, 73%) felt a need to improve their level of physical activity, while more than half (n=158, 58.5%) felt a need to improve their nutrition. Two thirds of current smokers wanted to cut down or stop smoking (n=31, 67.4%), and of those who drank alcohol, 13.3% (n=34) felt a need to reduce their intake and/or frequency. Of the respondents who reported mental health concerns, all wanted to improve their mental health and nine (13.2%) wanted help to achieve this.

Table 2. Readiness to improve health or change lifestyle behaviours, and desire for help.

Self-identified Need to Change?	Want Help?	Physical Activity n(%)	Nutrition n(%)	Smoking n(%)	Alcohol n(%)	Mental Health n(%)
Yes	Don't want help	125(46.3)	101(37.4)	14(30.4)	28(10.9)	59(86.8)
	Want future help	23(8.5)	14(5.2)	11(23.9)	4(1.6)	6(8.8)
	Want help now	49(18.1)	43(15.9)	6(13.0)	2(0.8)	3(4.4)
No		73(27.0)	112(41.5)	15(32.6)	221(86.0)	202(74.8)
Missing					2(0.8)	

Most respondents (n=207, 76.7%) indicated they would like to engage with health promotion activities in one or more areas of interest. The most frequently identified interests were age and fitness level appropriate physical activity (n=141, 52.2%), nutrition (n=107, 39.6%), and weight loss (n=53, 19.6%).

Discussion

The characteristics of the study sample suggest the results can be generalised to the study population, and may be useful in guiding further research. In terms of distribution of sex and age, the sample was representative of the Brigade, wider Army and ADF.[30] In relation to service type, the study sample was similar to this and other PT Brigades, with more PT than FT personnel. In the wider Army[30] these proportions are reversed with more FT than PT personnel, suggesting further research is required to explore the health issues concerning FT members. Preventable risk factors for cardiovascular disease assessed in this study include hypertension, overweight, obesity, insufficient physical activity, poor nutrition and tobacco smoking.[3]

Overweight, obesity, nutrition and physical activity

The findings of overweight and obesity were not dissimilar to recent ADF statistics. In 2010 overweight and obesity were reported at 63.1% of men and 37.5% of women in the FT Army, and 67.8% of men and 38.7% of women in the PT Army.[9] In our sample, although an awareness of the importance of nutrition and weight management and a desire to improve nutrition was evident, the daily fruit and vegetable intake was well below Australian

recommendations.[28] Results also show high levels of participation in, and awareness of, the need for regular physical activity. However most respondents also felt a need to improve their level of physical activity, and this may be due to the requirements of military service and regular fitness testing. Despite ADF health and fitness standards, overweight and obesity was prevalent in our study, with more men than women affected and rates increasing with age, which is consistent with civilian[3] and ADF[9] trends. Our findings suggest that having information and knowledge does not necessarily positively influence individual health behaviours, and collaborative strategies to improve physical activity and nutrition through development of healthy policy, supportive environments, and personal skill are required for this cohort.

Smoking

It is has been established that smoking occurs at higher rates in those with lower levels of education in both civilian[31] and military populations,[2] and this is also reflected in our sample. While higher smoking rates among FT respondents may be related to lower levels of education, other factors such as deployment,[2,7] peer behaviour and role modelling[32] have also been found to promote smoking behaviour and may have been influential. A study of United States military recruits reported non-smokers were more likely to start smoking if they perceived the majority of their peers smoked, their leaders/instructors used tobacco products, and their roommate smoked.[32] A similar influence may exist for FT personnel who are professional soldiers required to work well in teams and exhibit high levels of discipline within a hierarchical chain of command and respect. FT members are more likely to deploy overseas, undergo intensive training for prolonged periods, forming close-knit groups, and be required to conform to team behaviours. Our findings suggest further research is required to explore the influence role modelling has on smoking behaviour in the FT Army and training environments, particularly as trainees are most vulnerable to role modelling by leaders in these settings. Considering smoking restrictions in training establishments have been found to be effective[7] and many smokers in our study wanted to cut down or stop smoking, workplace policy should be used to create supportive environments and strengthen community action, to support non-smokers, personnel wanting to become non-smokers, and a smoke free workplace.

Mental health and stress

In our study, both mental health concerns and stress affecting daily life were identified more frequently by FT personnel. This may be associated with some of the unique characteristics of FT service, which were not assessed in this study. Significantly, most personnel who reported experiencing mental health concerns indicated they did not want help to address these. Reluctance to seek assistance is of particular concern as it is thought to be associated with the under-reporting of mental health issues.[1,33] This may be a consequence of a military culture and barriers that encourage soldiers to hide health and wellbeing issues due to fear of administrative and disciplinary outcomes, adverse effects on career progression and employment, and stigma.[33] Internationally, stigma appears to be a significant barrier to seeking mental health care within Western military forces,[34] and in recent ADF mental health research, the highest rated stigmas associated with seeking help were 'being treated differently' (28%) and 'harm to career' (27%), with concern for 'reduced deployability' (37%) being the highest rated barrier to seeking help.[1]

Alcohol

Another focus area that is not unusual for military populations is the use of alcohol at levels of increased health risk.[35,36] In 2011, a review into the ADF's 'unhealthy drinking culture' was announced,[5] and in 2012 recommendations were released to address Defence culture and alcohol related harm.[6] Similar use of alcohol amongst personnel was also supported in our findings, with over half of those surveyed reporting alcohol consumption at levels of increased risk. A number of factors were identified in the 2012 review as having a potential to influence and perpetuate the ADF's 'unhealthy drinking culture'.[5] In our study, factors that may support drinking at levels of increased risk included the male dominated workplace, large population of young men, common understanding of the 'work hard play hard' colloquialism, and role modelling by leaders. Many young leaders are aged between 20-35 years, and these personnel hold positions of authority over junior and often younger personnel, which may result in leaders modelling alcohol consumption at levels of increased risk, thereby perpetuating similar behaviour in subordinates. While more than half the sample in our study consumed alcohol at levels of increased risk, most did not wish to reduce their intake. This indicates respondents were either unaware of the recommended limits to reduce alcohol related risk, or their behaviour was not influenced by the recommendations despite having an awareness. Another potential influencing factor could be the threat of disciplinary action, which may deter personnel from seeking help for alcohol related concerns.[37] Programs that strengthen community action and engage young leaders to model healthy

behaviour are needed to influence 'drinking culture' and create change in this area.

Men's and women's health

Our sample was predominantly male, which is reflective of the general military population. As a population, men are known to be a 'hard to reach group';[38-40] less likely to seek help for health concerns.[3] More specifically, the Army is stereotypically seen as a masculine environment and this has a significant potential to influence health. In a study of masculinity and health behaviors in Australian men, those identified as having higher traditional masculinity scores reported more health risk behaviours and less health promoting behaviours relating to nutrition, sun protection, stress and anger management, talking about concerns, expressing feelings, and consulting a health professional when feeling down or depressed for more than one month, or experiencing unfamiliar physical health symptoms.[41] Therefore, it was encouraging to find the majority of our predominantly male sample indicated a desire to participate in workplace health promotion, with their health interests being similar to the risk factors identified in the study. This shows the defence workplace setting can provide important health promotion opportunities to engage this community. However, there was an exception to this in relation to seeking help to resolve and prevent mental health problems. Our study highlights an ongoing need for mental health support and health promotion initiatives in areas that promote personal skill development and empowerment. Policy to create supportive environments where personnel feel able to seek help without adverse consequences or stigma is also needed.

Interestingly, this current study found no association between smoking and gender or alcohol use at levels of increased risk and gender, which differs from Australian trends where these risk factors are more prevalent in adult males.[3] The reasons for this are likely to be complex, relating to military culture, and conformity to social norms and traditional male behaviours, where female personnel are more likely to attempt to 'fit in' to the male dominated environment to gain acceptance[42] amongst their male counterparts. Further research is required to examine the influence of military culture on women's health behaviours to establish whether this or other reasons might be contributing factors, and to investigate the efficacy of potential health promotion interventions.

Limitations

This study has a number of limitations. Due to the relatively small numbers of personnel in this survey, self-reporting, potential for healthy volunteer bias, and either non-disclosure or under-reporting of increased risk health behaviours, generalisations of our findings to other groups of military personnel should be undertaken with caution. The low numbers of FT and female respondents in the sample also limit generalisability of the findings to these groups.

Conclusion

Substantial collaboration with Brigade unit commanders and personnel occurred during this study, representing an important step towards community engagement and successful future workplace health promotion. Personnel shared similar risk factors and health lifestyle behaviours relating to overweight and obesity with the Australian population, and expressed an interest in improving these. Health promotion programs and strategies that influence policy, strengthen community action, engage young leaders, and create supportive environments for cultural change are needed to address these issues. While mental health concerns were identified in this study, a reluctance to seek help was evident. The increased prevalence of mental health concern among FT compared with PT personnel indicated further research and tailored programs may be needed to specifically address the individual needs of each group. Programs that work toward creating a culture of acceptance and understanding around mental disorders are needed to encourage personnel to seek help, and reduce potential for under or non-reporting. This study has identified areas where more research is required, particularly into military culture and its influence on health and lifestyle behaviours. Future research should guide policy and ADF health promotion programs that can assist individuals and defence workplace communities to practise healthy behaviours. In addition, our study provides valuable information about this Brigade to inform health promotion development and resource distribution to address the needs of this unique workplace population.

Acknowledgement

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Disclosure

The principal researcher was an employee of the ADF at the time of the study.

Corresponding author: Sharryn Batt
Email: s.batt@murdoch.edu.au
Authors: S. Batt[1], P. Geerlings[2], C. Fetherston[1]
Author Affiliations: [1] Murdoch University - School of Health Professions
[2] Murdoch University - Centre for University Teaching and Learning

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Effects of Penthrox® (methoxyflurane) as an analgesic on cardiovascular and respiratory functions in the pre-hospital setting

H F Oxer

Introduction

Methoxyflurane (Penthrox®) was initially introduced as an analgesic into Australian ambulance services in 1974. The last 40 years have seen it become extensively used in all government and non-government emergency ambulance services as well as private ambulance providers and patient transport sectors. Its short onset of action and effective analgesic properties makes the drug an important pain relief option in pre-hospital management. Additionally, methoxyflurane has minimal side effects, including negligible effects on the cardiovascular system and respiratory system, and does not interfere significantly with the examination of the patient on arrival at hospital.[1]

Methoxyflurane for analgesic use is manufactured and supplied globally from Australia as Penthrox®.

The Australian prescriber information states that methoxyflurane is to be administered only to cardiovascularly stable patients, and to those without respiratory depression. This seems to imply that methoxyflurane, even when given in the recommended analgesic doses via the Penthrox® dose limiting inhaler, may decrease blood pressure (BP), pulse rate, or respiratory rate; however this is not reported in clinical practice.

Although there is a large body of published literature supporting the efficacy and safety of methoxyflurane at analgesic concentrations,[2] there is a need for current day supporting studies confirming that this medication does indeed meet modern and regulatory standards, and is safe and effective at analgesic doses.

This is a retrospective, observational study of case records of 590 de-identified ambulance patients. They were investigated in a real life setting (pre-hospital ambulance transport) to ascertain whether methoxyflurane could be shown to have any impact on cardiovascular and respiratory functions. The study objectives were to ascertain whether any deleterious effects occurred on:

1. Cardiovascular function (systolic blood pressure, and pulse rate)
2. Respiratory function (respiratory rate)

Methods

St John Ambulance in Western Australia operates the state ambulance service, over an ambulance authority area covering a million square miles – 2.5 million km2 (more than a third of the land area of the continent of Australia). A data collection system using an iPad® has allowed the electronic collation of numerical data. For the purposes of this study, it has provided an accessible mode to retrospectively analyse data on the physiological effects when administering methoxyflurane to ambulance patients in pain.

The Penthrox® inhaler is a hand-held inhalation device (Medical Developments International Limited, Scoresby, Victoria, Australia). The concentration inhaled is variable, depending on individual tidal volume, breathing patterns and airway geometry. However, simulation of in vitro inhalation and exhalation through the inhaler shows that the inhaled concentration of methoxyflurane using the Penthrox inhaler is between 0.1% and 0.7% depending on whether the dilutor hole is open or covered.[3] The latter enables an increased concentration of methoxyflurane to be inhaled by patients in more severe pain to provide a faster onset of analgesia. As the methoxyflurane is self- administered, the patient maintains control of their pain management. The maximum quantity available to the subject per dose is 3 mL, i.e. one vial loaded into the inhaler. After an initial loading dose of 6 to 10 breaths through the

device (henceforth described as 1 administration), the patient is encouraged to take a few breaths through the device every few minutes thereafter as required. A single vial would only provide analgesia for 20-25 minutes if inhaled continuously, or up to at least 1 hour if used intermittently. A second vial of 3 mL methoxyflurane may be administered when the initial vial has been exhausted.

The data were recorded on the IPad device by the paramedics and volunteer ambulance officers, as part of the patient care process. Staff were aware that the data may be analysed for research purposes. Methoxyflurane was administered under a Clinical Practice Guideline allowing for 3 ml to be given via inhaler, which may be repeated once. It was not practical, or necessary, to determine the exact dose administered during any one episode.

A search of the iPad® data was conducted for all cases that had received methoxyflurane between 15 August 2011 and 4 April 2012, and had at least three sets of observations for systolic BP, pulse rate, and respiratory rate, and where there was no other record of analgesic use. Although this may have biased the selection of the data, three sets were chosen to establish a trend, and to establish whether a single out-of-limits reading was supported by the others, or was just an entry error. Values that were below the normal limits that we set for the 3 parameters were analysed separately:

1. Pulse rates that were lower than 60 beats/min, or above 100 beats/minute.;
2. Systolic BP readings that were lower than 90 mm Hg, or above 140 mm Hg;
3. Respiratory rates that were lower than 11 breaths/minute, or above 30 breaths/minute.

These limits are similar to those quoted for average values in healthy people, and are widely accepted, with minor variations.[4,5]

It is recognised that many healthy individuals have resting rates outside these figures.

The recorded brief patient incident history was also reviewed as necessary for confirmatory information. For each patient, mean values for systolic BP, pulse rate and respiratory rate were calculated for 4 time periods: before methoxyflurane administration, 0-10 minutes after administration was initiated, 11-20 minutes after administration was initiated, and 21-30 minutes after administration was initiated. Henceforth, all references to 'before' and 'after' methoxyflurane administration refer to before and after the start of methoxyflurane administration.

Results

Patient Disposition

Only patients with 3 or more observations were included in the analysis, which was carried out using SAS version 5.2. Five hundred and ninety patients fulfilled this criterion and were included in the study, with over 2063 valid individual sets of observations recorded for these patients.

Most patients included in this report had 3 sets of observations of their vital signs carried out (396 patients, 67.1%). One hundred and twenty four patients had 4 observation sets, (21.0%), and most of the remainder had 5 or 6 sets, with 7 patients (1.2%) having over 6 sets of observations.

The majority of patients received 1 administration of methoxyflurane (551 patients, 93.4%). Thirty eight patients received 2 administrations of methoxyflurane, representing 6.4% of the total. One patient (0.2%) received 3 administrations of methoxyflurane.

Patient Demographics

The mean age of the patients was 50 years (SD: 24 years), and they ranged from 5 years of age to 99 years of age. The majority of patients were 18 years of age and over (537 patients, 91.1%) with 47.8% (282) aged 50 and above, and 19.8% (117) over the age of 75 years. The ratio of male to female patients transported by ambulance over the last complete year were 47% male: 58% female. The ratio for those who received methoxyflurane was 44% male: 55.9% female. This probably reflects the greater number of surviving females to males in the old, illness and injury- prone age group.

A summary of patient demographics by indication is given in the Table.

Table. Patient Demographics by Indication

Indication (by System/Organ Class)	Number of patients (%)
Abdominal	86 (14.6)
Cardiac	7 (1.2)
Environmental	6 (1.0)
Geriatric/Debility	4 (0.7)
Illness (unspecified)	18 (3.1)
Musculoskeletal	118 (20.0)
Neurological	6 (1.0)
Obstetrics/Gynaecology	10 (1.7)
Trauma	302 (51.2)
Urology	6 (1.0)
Other	27 (4.6)
Drug/Alcohol	*1 (3.7)*
Endocrine/Metabolic	*1 (3.7)*
Infectious	*1 (3.7)*
Not stated	*21 (77.8)*
Psychosocial	*1 (3.7)*
Respiratory- C.A.L./C.O.A.D.	*1 (3.7)*
Respiratory- R.T.I.	*1 (3.7)*

C.A.L.: Chronic Airflow Limitation; C.O.A.D.: Chronic Obstructive Airways Disease; R.T.I.: Respiratory Tract Infection

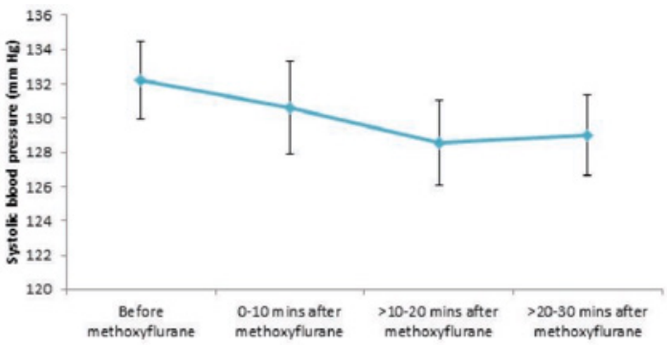
Just over half the patients presented with trauma (302 patients, 51.2%). Trauma comprised mainly domestic trauma (injuries received in the home), but also included sporting injuries, motor vehicle accident trauma, assault- related injuries, industry-related injuries, and undefined trauma. The next most common indications were musculoskeletal problems (118 patients, 20.0%) and abdominal problems (86 patients, 14.6%).

Overall Changes in Vital Signs

Systolic BP

Figure 1 shows the difference in systolic BP before and after methoxyflurane administration.

Figure 1. Mean (95% CI) systolic BP before and after methoxyflurane administration



Overall, systolic BP fell slightly after methoxyflurane administration from a mean of 132.2 mm Hg (SD: 23.9) to 130.6 mm Hg (SD: 23.7) 0 to 10 minutes after administration, and then plateaued to around 129 mm Hg between 10 and 30 minutes after administration. All mean values across all patients for each time period were well above 90 mm Hg and within normal limits. (110-140mm Hg).

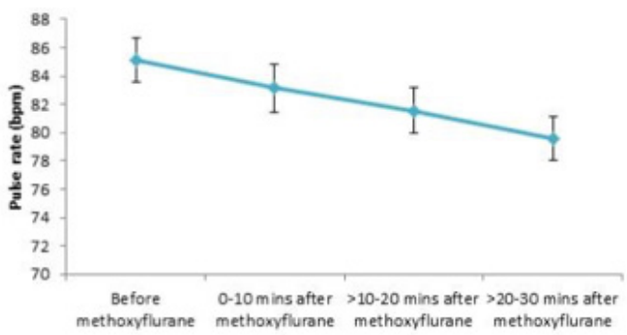
Nearly all patients (>95%) both before and after methoxyflurane administration had levels of systolic BP within normal limits. The proportion of patients that had 'abnormal' values (both above and below our defined normal levels) decreased after methoxyflurane administration, and there was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal systolic BP.

In general, there was no particular pattern to the patients' systolic BP levels after methoxyflurane administration across age classes, other than an initial decline, associated with relief of suffering. Additionally, there was little overall pattern in systolic BP levels among patients presenting with different indications after methoxyflurane administration. There was, however, a greater early decrease in systolic BP after methoxyflurane inhalation in cardiac patients and some with unspecified illnesses, before levels settled at their previous levels within 30 minutes of inhalation. However, much of this large initial decrease can be accounted for by individuals with extreme baseline values; for example, one cardiac patient had a systolic BP of 220 mm Hg before methoxyflurane inhalation decreased the elevation associated with the patients initial physiological response to pain.

Pulse rate

Figure 2 shows the difference in pulse rate before and after methoxyflurane administration.

Figure 2. Mean (95% CI) pulse rates before and after methoxyflurane administration



Overall, pulse rate fell continuously after methoxyflurane administration from a mean of 85.1 beats/min (SD: 16.8) to 79.6 beats/min (SD: 13.5) between 20 and 30 minutes after administration. All mean values across all patients for each time period were well above 60 beats/min and within our range of normal resting limits

Most patients (>80%) both before and after methoxyflurane administration had pulse rates within normal limits. The proportion of patients that had abnormal values (both above and below our defined normal levels) decreased after methoxyflurane administration, and the proportion of values within normal limits increased steadily between 0 and 30 minutes after methoxyflurane inhalation. There was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal pulse rates.

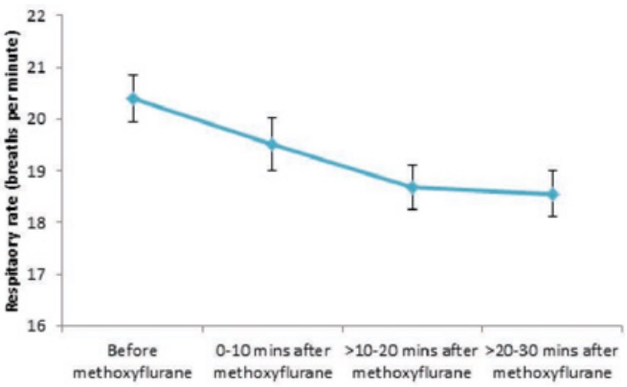
When considering methoxyflurane administration by age classes, the sharpest decrease was found in children under the age of 12; pulse rates in these patients fell by approximately 10 beats/minute within 10 minutes of methoxyflurane administration, and pulse rates remained around that level until at least 30 minutes after methoxyflurane administration.

There was little overall pattern in pulse rate among patients presenting with different indications after methoxyflurane administration. There was, however, a relatively sharp and immediate decrease in pulse rate up to 30 minutes after methoxyflurane inhalation in patients who had had environmental-related injuries (such as bites or stings). Another unusual observation was that pulse rates increased after methoxyflurane inhalation in geriatric patients or those with debility. However, all changes were small and were within normal limits.

Respiratory rate

Figure 3. shows the difference in respiratory rate before and after methoxyflurane administration.

Figure 3. Mean (95% CI) respiratory rates before and after methoxyflurane administration



Overall, respiratory rate fell slightly after methoxyflurane administration from a mean of 20.4 breaths/minute (SD: 4.9) to 18.6 breaths/minute (SD: 3.9) between 20 and 30 minutes after administration. All mean values across all patients for each time period were well above 10 breaths/minute and within our normal limits (12 – 18 breaths/minute for adults).

No patient had a respiratory rate of less than 10 breaths/minute before or after methoxyflurane inhalation. Most patients (>88%) both before and after methoxyflurane administration had respiratory rates within normal limits. The proportion of patients that had abnormal values above normal levels decreased after methoxyflurane administration, and the proportion of values within normal limits increased steadily between 0 and 30 minutes after methoxyflurane inhalation. There was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal respiratory rates.

In general, respiratory rate decreased slightly across age classes after methoxyflurane administration, except for a rise in adolescents from 19 breaths/minute before methoxyflurane to 21 breaths/minute within 10 minutes of receiving methoxyflurane. However, there was a great deal of variation in these patients as indicated by the large standard deviation, so it is likely that a handful of outliers may have caused this aberrant result. Patients in most age classes exhibited a stabilising of their respiratory rates after 10 minutes of receiving methoxyflurane, except children under the age of 12 whose respiratory rates continued to decrease 20-30 minutes after methoxyflurane administration.

Consistent with other vital signs measured, there was little overall pattern in respiratory rate after methoxyflurane administration among patients presenting with different indications. An unusual result was the large increase in respiratory rate up to 10 minutes after methoxyflurane inhalation in geriatric patients or those with debility, although there was significant variation around the mean in this indication group. However, all changes were small and were within normal limits.

Lower than normal Values in Vital Signs

A subset of the data was extracted that only included patients with any systolic BP values of less than 90 mm Hg, a pulse rate of less than 60 beats/min, or a respiratory rate of less than 10 breaths/minute after methoxyflurane administration. The lower values exhibited after methoxyflurane inhalation were compared with their values before inhalation, to ascertain whether there was a possibility that the below normal values were caused by methoxyflurane. The patients remained clinically normal throughout.

There were 4 patients who had a systolic BP of less than 90 mm Hg after methoxyflurane inhalation. Three of these patients already had values at or below 90 mm Hg before methoxyflurane, and their BP only fell by 5 mm Hg after methoxyflurane. One patient had a decrease of 20 mm Hg in systolic BP after methoxyflurane. This patient had a systolic BP of 118 mm Hg before methoxyflurane that fell to 85 mm Hg within 10 minutes of receiving methoxyflurane, before rising to 95 mm Hg 20-30 minutes after methoxyflurane.

As with systolic BP, patients who exhibited low pulse rates after methoxyflurane inhalation also had low levels before inhalation. There were 27 patients who had subnormal levels of pulse rate after methoxyflurane inhalation. Twenty one of these patients already had values at, or below, 60 beats/min before methoxyflurane and their pulse rates only fell by 6 beats/min at the most after methoxyflurane. Six patients had falls of up to 10 beats/minute in pulse rate after methoxyflurane.

Their other vital signs, however, were within normal limits and they were not otherwise adversely affected by methoxyflurane inhalation or becoming symptomatically hypotensive.

No patients, either before or after methoxyflurane inhalation, exhibited respiratory rates of less than 10 breaths/minute.

Discussion

Overall, systolic BP fell slightly after methoxyflurane administration 0 to 10 minutes after administration and then plateaued between 10 and 30 minutes after administration. All mean values for each time period were well above 90 mm Hg and within normal limits. Nearly all patients (>95%) both before and after methoxyflurane administration had levels of systolic BP within our normal limits. The proportion of patients that had values both above and below our defined normal levels decreased after methoxyflurane administration, and there was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal systolic blood pressure.

In general, there was no particular pattern to the patients' systolic BP levels after methoxyflurane administration across different age groups or indications. The few patients who exhibited low systolic BP after methoxyflurane inhalation tended also to have low levels before inhalation.

Overall, pulse rate fell continuously over 20 to 30 minutes after methoxyflurane administration. All mean values for each time period were well above 60 beats/minute and within normal limits. Most patients (>80%) both before and after methoxyflurane administration had pulse rates within normal limits. The proportion of patients that had values both above and below normal levels decreased after methoxyflurane administration, and the proportion of values within normal limits increased steadily between 0 and 30 minutes after methoxyflurane inhalation. There was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal pulse rates.

The sharpest decrease was found in children under the age of 12; pulse rates in these patients fell by approximately 10 beats/min within 10 minutes of methoxyflurane administration, and remained around that level until at least 30 minutes after methoxyflurane administration. There was little overall pattern in pulse rate among patients presenting with different indications after methoxyflurane administration. As with systolic BP, patients who exhibited low pulse rates after methoxyflurane inhalation also had low levels before inhalation.

Overall, respiratory rate fell slightly over 20 to 30 minutes after methoxyflurane administration. All mean values for each time period were well above 10 breaths/minute and within normal limits. Most patients (>88%) both before and after methoxyflurane administration had respiratory rates within normal limits. The proportion of patients that had raised levels decreased after methoxyflurane administration, and the proportion of values within normal limits increased steadily between 0 and 30 minutes after methoxyflurane inhalation. There was no evidence that methoxyflurane inhalation increased the probability of exhibiting abnormal respiratory rates.

In general, respiratory rate decreased slightly across age classes after methoxyflurane administration, except for a rise in adolescents. Consistent with the other vital signs measured, there was little overall pattern in respiratory rate among patients presenting with different indications. No patients, either before or after methoxyflurane inhalation, exhibited respiratory rates of less than 10 breaths/minute.

There were no cases of patients becoming symptomatic resulting from decreased systolic BP, pulse rate, or respiratory rate that was associated with methoxyflurane administration.

The evidence from recent clinical trials on methoxyflurane supports the results from this retrospective, observational study. No clinically significant changes were observed for vital signs (heart rate, respiratory rate, BP or temperature) in the clinical study of methoxyflurane in patients undergoing a bone marrow biopsy procedure.[6] Similarly, in the clinical study of methoxyflurane in patients presenting to an Emergency Department with minor trauma,[7] there was little change in systolic BP, diastolic BP, respiratory rate, heart rate, heart rate rhythm (regular and irregular rhythm specified) between the evaluations in patients in the methoxyflurane and placebo groups; indeed the results were comparable to that of the placebo group.

In a similar study to the present one, a retrospective, observational review of patient care record forms encompassing patients administered methoxyflurane or fentanyl for the prehospital management of presumed visceral pain was conducted by the Western Australian Ambulance Service between January 2004 and February 2006.[8] They reported that methoxyflurane caused a mean reduction in systolic BP 5 minutes after the initial dose of methoxyflurane of 5.7 mm Hg (median 10 mm Hg). The effects of methoxyflurane on pulse and respiratory rates were minimal, and consisted of slight falls in both

parameters after methoxyflurane administration. In the majority of cases, methoxyflurane affected pulse rate favourably towards normal values, but the changes were not significant. Respiration was likewise affected minimally by methoxyflurane administration; mean respiration declined by 1.7 breaths/minute initially and by 2.1 breaths/minute on hospital arrival. No patients became bradypnoeic.[5]

One case (in forty) of hypotension was recorded in study of methoxyflurane use during emergency transportation. However this occurred following a surgical procedure, for which preoperative medication and an anaesthetic agent were administered.[8]

In a study in trauma patients, BP and heart rate remained stable following methoxyflurane administration, and in cases where the patient's haemodynamic condition was initially impaired, there was an appreciable improvement i.e. increased differential BP and stronger heart beats. There was no respiratory depression, and breathing was often normalised following the onset of analgesia. These observations led the authors to conclude that methoxyflurane has a stabilising effect on cardiorespiratory function and limits shock.[7]

In a long-term data linkage study, it was reported that in patients administered methoxyflurane no increased risk of disease occurrence was observed in any of the disease groups under investigation when compared with prehospital care patients who were not administered methoxyflurane.[8 9]

Conclusion

The administration of low dose methoxyflurane used for analgesia did not produce any deleterious effect on cardiovascular or respiratory parameters in this study whereby patients became symptomatic. The observations indicate that in this otherwise unselected, large group of presentations who had received methoxyflurane for pain, there were no deleterious effects on pulse rate, systolic BP, or respiratory rate, and this is supported by the narrative notes. The initial changes in vital signs seen are consistent with reduction in pain and suffering. It is expected that elevated pulse rate, systolic BP or respiratory rate usually observed in patients with pain and suffering would decrease initially, and then plateau on commencement of analgesia as part of physiological responses to pain.

A precautionary statement in the Product Information document, warning against using methoxyflurane in patients with cardiovascular instability, or with respiratory impairment, appear largely unwarranted in the practical situation of pain relief. Such a warning may be an historical artefact of labelling from when methoxyflurane was used at much higher doses as an anaesthetic. There is no evidence, in this observational study of retrospective data, to indicate that administration of methoxyflurane in low, controlled analgesic doses would result in decreased systolic blood pressure, pulse rate or respiratory rate of clinical significance. These findings are supported by the absence of any reports in recent clinical trials,[1,2,6,7,8,9-16] in the literature, or with regulating authorities, that report such sensitivity, despite over four million doses dispensed during nearly forty years of use in Australia, and elsewhere.

The results of this study further support the conclusion that methoxyflurane is safe, simple to use and is an effective inhaled analgesic agent, with no significant physiological or toxic side effects at the prescribed analgesic doses.

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Aligning Defence Environmental and Occupational Health (EOH) Capability with Future Requirements: The 4th Australian Defence Force EOH Conference

D. Licina[1], A. Brittain[1], A. Tout[2], T. Strickland[3], D. Taplin[4]

Introduction

Eleven years ago, the Australian Defence Force (ADF) held the third Environmental and Occupational Health (EOH) Conference. Much has changed within the Pacific region and the world since that time. In recent years, ADF EOH personnel have supported numerous missions across the spectrum of operations. These missions included humanitarian assistance such as Exercise Pacific Partnership, disaster relief during Operation Philippines Assist, conflict support in Afghanistan and Iraq; and post conflict support in Timor-Leste and the Solomon Islands. Individuals who deployed in support of each of these missions, and more, gathered at Gallipoli Barracks outside of Brisbane from March 4-6, 2015 to share their first hand experiences to inform policy development and build meaningful partnerships during the 4th ADF EOH Conference.

Presenters and participants represented the various ADF Services, interagency partners such as the Department of Foreign Affairs and Trade and the Department of Veterans Affairs, academia, as well as our international partners from the New Zealand, United Kingdom and the United States Defence Forces. The conference opened with a brief presentation of what the future might hold for the EOH profession within the Pacific Region and an overview of strategic efforts underway by the ADF Joint Health Command (JHC), the conference co-sponsor along with the Australian Army 1st Preventive Medicine Company. Six sessions followed over three days ranging in topics from EOH on exercise and deployment to health surveillance informing health intelligence. The remaining sections of this commentary will outline the anticipated future challenges for the EOH profession, strategic initiatives underway within JHC to support EOH, key highlights from each of the conference sessions, and concluding thoughts for the Defence EOH community to ponder.

Future EOH Challenges

Countries within the Asia-Pacific region have and continue to remain vulnerable to climate threats such as cyclones and tsunamis, environmental degradation, political instability, and terrorist threats. They also suffer from poverty, population displacement, infectious diseases, decreasing access to potable water sources and inadequate sanitation, which all lead to higher rates of morbidity and mortality.[1] Many countries within the region are also experiencing high rates of population growth, increased life expectancy, new technologies which have improved survivability of historically fatal illnesses and disease, as well as overall increases in per capita income. While these issues could be interpreted as successes and opportunities, they place additional pressures on many fragile health systems within the Pacific region.[2]

Furthermore, higher total fertility rates place increased demand on maternal, newborn, and child health services in the near term while generating secondary long term effects such as increased health-care needs for a larger and older population.[3] Vector borne diseases continue to generate significant costs to both health and national economies as seen in the Solomon Islands, which has one of the highest global incidence rates of malaria outside of Africa.[4] Non-communicable diseases such as cardiovascular disease, cancer, and diabetes are creating a double burden of chronic and infectious diseases for developing countries in our region. Men in Fiji, Solomon Islands, Vanuatu, Samoa, and Tonga die prematurely (less than age 60) from non-communicable diseases at rates higher than the average of all low-income countries globally.[3] Fiji in particular has a rate more than double the global average, with the third highest prevalence rate of diabetes in the world.[5] Placing these macro issues into a micro level financial context, a single

patient requiring insulin in Vanuatu consumes the equivalent drug allocation of 76.4 citizens.[3] These figures are clearly not sustainable for these countries and our region.

So how do these current and anticipated regional health challenges relate to the EOH profession? In many countries within the Pacific region, the military plays a key role in both disaster response as well as providing direct patient care to both military and civilian populations. These broader issues will clearly put strains on a limited host nation, and specifically military disaster response and public health capacity, generating an increased reliance, and in some cases dependency, upon international development and military partners like us. So therein lies an opportunity for the EOH community to not only sustain ongoing Force Health Protection efforts to ensure the viability of military personnel deployed in the region, but potentially build partner nation EOH military capacity to address these issues now instead of allowing this dependency to endure.

The United States Department of Defense has leveraged health, to include environmental and public health, to build partnerships with military and civilian organisations throughout the world. Their health engagement activities include deploying US Navy hospital ships with partner nation EOH military personnel from the ADF, New Zealand Defence Force (NZDF), and United Kingdom Ministry of Defence to provide humanitarian assistance and public health training in the Pacific region. They also have forward-deployed research laboratories in Thailand and Myanmar that work with both the military and civilian sector to support ongoing research leading to advances in force health protection measures against infectious diseases, neglected tropical diseases and HIV/AIDS. These laboratories collaborate with organisations such as the ADF Army Malaria Institute and support the World Health Organization Global Outbreak Alert and Response Network collaboration that provides a global good to both military and civilian organisations within our region.

It is important to consider how these formalised military-to-military partnerships between developed nations can support the ongoing challenges discussed previously within the Pacific region. For example, when the ADF offers EOH support during disaster responses and humanitarian assistance missions, how does it align with existing programs managed by the host nation Ministry of Health to lessen the disease burden? What ways can the ADF partner in EOH with nations in the region prone to the aforementioned challenges and how can it serve as a pillar in supporting health, security and economic prosperity in the Pacific Region? Solutions to these broad questions will take time to develop.

ADF JHC Initiatives

At the strategic level within the ADF, JHC continues to work with the Groups and Services and NZDF partners through the Defence *Preventive Medicine* Working Group to further develop Health Manual Volume 20 - Preventive Medicine and Health Manual Volume 21 - *Pest Control.* The manuals provide direction to Preventive Medicine and Environmental Health personnel involved with the general principles of preventive medicine in support of the requirements outlined in the Australian Defence Force Publication 1.2.2. - *Force Health Protection.* Both health manuals cover subjects of environmental health, occupational hygiene and control of disease vectors and other pests in order to prevent casualties and protect the ADF members' health. These programs are managed by EOH personnel in the ADF and have an operational focus born out of the requirement to prepare for war and adapt for peace. The DPMWG was chartered in 2011 to facilitate the subject matter expert review and publication of these manuals. It is acknowledged the ongoing review process has been lengthy. JHC recognises these manuals provide much needed guidance to the Services, but that they are not published in full. The JHC EOH Staff continue to work a modified approval process to expedite the publication of the remaining parts in each of these manuals. The ADF Service Director Generals for Health agreed with the proposed process and are seeking formal approval with the Surgeon General ADF.

Additionally, JHC has been engaged with the Groups and Services in addressing the ongoing Occupational Medicine and Occupational Hygiene (OMOH) capability shortfall within the ADF. Personnel from both the EOH and the Work Health and Safety communities have supported initiatives and studies on this topic since the F111 Board of Inquiry was published in 2001. Unfortunately, ongoing OMOH personnel shortfalls continue to prevent the ADF from achieving an effective OMOH practitioner capability and proactive level of maturity. This vulnerability and liability was exposed during the investigation undertaken by Comcare in 2009 which resulted in the Hazardous Chemical Enforceable Undertaking in 2010. Bearing this in mind, as well as other recent initiatives that failed to deliver a solution to the capability shortfall, JHC is developing a Defence Work Health and Safety Committee (DWHSC) concept paper outlining options to support ADF OMOH requirements.

The goal is to submit the concept paper to the DWHSC co-chaired by the Vice Chief of Defence Force and the Deputy Secretary Defence People Group. With their endorsement, an ADF OMOH Working

Group would initiate planning efforts to deliver a mature capability level for uniformed personnel. Joint Health Command acknowledges big changes take time and remains committed to assisting ADF EOH professionals in achieving their mission while supporting Commanders in meeting their due diligence obligations under the Work Health and Safety Act. These combined initiatives will support some of the requirements identified during the ADF EOH Conference.

Session Highlights

Over the three-day ADF EOH Conference, 35 presentations were conducted with the presenters participating in four panel discussions. Below are the key points raised during these discussions. These points are the views of those present and not officially endorsed by JHC.

Table 1. Panel Discussion 1: Strategic perspectives from senior officials & Policy perspectives on how Service EOH is supporting Defence requirements

Panel Focus	Fundamental Input to Capability	Key Points
Opportunities for inter-service and international EOH collaboration	Doctrine	There is a need to clearly define the role and competencies of EOH Officers and Technicians in policy and doctrine, the current scope is too broad and may result in professionals assuming missions and tasks beyond the original objectives of the trade
		There is an assumption that the EOH profession can operate in the civilian-military space without supporting policy and doctrine to ensure effectiveness and legalities are addressed
	Organisation	Work Health Safety Branch is a shared service for the ADF, uniformed ADF EOH and Preventive Medicine personnel should serve in a similar capacity
		Different safety management systems employed by the Services could be generating hazards for the ADF, there is a need to standardise the process across Defence
	Training	A common set of Defence EOH standards should be developed among partner nations, possibly leveraging the Chemical Biological and Radiological Memorandum of Understanding between the Australia, Canada, United Kingdom, United States and New Zealand (AUSCANUKUS+NZ)
		The ADF and NZDF should explore adopting the US Department of Defense Tri-Service Tech Guide 230 on exposure guidelines for deployed personnel via the AUSCANUKUS+NZ group
		ADF EOH training standards need to be examined to determine any associated liabilities when training partner nation civilian and military personnel
		There is a need to standardise EOH training within ADF, currently there are 46 different courses ranging from 2 days to 16 weeks. Should there be a role for Health Training Advisory Group and Air Force Health Operational Conversion Unit in this process?

(Endnotes)

1 U.S. Army Public Health Command. Technical Guide 230 Environmental Health risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel. Aberdeen Proving Ground, Maryland 2013. Available at http://phc.amedd.army.mil/PHC%20Resource%20Library/TG230.pdf, accessed 12 March 2015.

Table 2. Panel Discussion 2: EOH on exercise and deployment

Panel Focus	Fundamental Input to Capability	Key Points
Institutionalising evolving roles	Doctrine	Heath threat assessments are ad hoc in how, where, when, and by whom they are conducted; it is currently a missed opportunity to inform health intelligence that should be clarified in policy and guidance (e.g. ADF Health Manual Volume 20)
		Exposure standards require consistent approach for both deployed and garrison settings
	Equipment	Significant lag time from when modern technology is identified to fill a capability shortfall and when it is fielded within the ADF, consideration should be given to a civilian contract/leasing to meet immediate needs
		The current ADF and NZDF deployment EOH kit is adequate but is not aligned to support reach back analysis. Consideration should be given to modelling U.S. Army Public Health fielded kits and leveraging laboratory analysis capability on a fee-for-service basis (e.g. Public Health Command-Pacific confirmatory EOH analysis where capable of being supported or ADF Defence Centre for Occupational Health contracts, etc)
	Training	Operational health planning should be to institutionalise in the Preventive Medicine Sergeant and Warrant Officer training continuum and for all 03 Officers and above
		New EOH Officers need initial tactical training to assist in contextualising didactic skills acquired in university (ADF and NZDF). Focus should be on practical application of skills especially in Field Hygiene. Consideration must be given to develop an ADF EOH / FHP Initial Officer Course.

Table 3. Panel Discussion 3: EOH in Garrison Operations and Academia

Panel Focus	Fundamental Input to Capability	Key Points
Shifting from deployment to garrison priorities	Personnel	Defence Work Health Safety Occupational Health policy should be amended to reflect the current environment (financial and personnel constraints) and Defence operations (internal Occupational Hygiene capability to support Defence). Policy mandating Level 2 Occupational Hygiene does not align with civilian terminology and is not achievable
		Suggestions to support personnel shortfalls in joint environments (e.g. Joint Health Command Butterworth Clinic) included: posting an Army Preventive Medicine Technician, deploying one as part of the Ready Command Group element (integral), or using locally employed resources. All suggestions were seen as improving the delivery of Force Health Protection
		A program to develop and mentor new ADF EOH professionals is recommended; focussed on practical application of EOH in the ADF. This will better prepare new ADF EOH personnel for isolated posting/ deployed roles
		The civilian mining workforce is softening. There is a downward trend in remuneration and numbers of Occupational Hygiene employed in this sector potentially providing a short term workforce solution for Defence
	Training	AIOH accreditation requirements were revised following the closure of the Deakin University Occupational Hygiene program. The University of Wollongong can offer course credit to ADF professionals who completed related studies. A Defence specific graduate certificate in WHS was discussed; if implemented/developed additional training to allow Australian Institute of Occupational Hygiene (AIOH) accreditation would be required
		Occupational Hygiene Training Association (OHTA) facilitates the ability to attain full membership of the AIOH via intensive five day workshops and examinations.
		Theoretical training provided to commissioned ADF EOH personnel (e.g. under– or post–graduate) needs to be complemented with practical exposures encountered in ADF workplaces—specifically in deployed environments
		Initial Occupational Hygiene training at the Graduate Certificate level is appropriate for the workforce —however this is not available through civilian institutions
		Due to civilian Occupational Hygiene training constraints; with these focused at the Masters level (Australian Qualifications Framework 9 which aligns with Certification under the AIOH)—it is unlikely Defence will achieve Masters qualified personnel in the medium term. Developing Masters level qualified personnel requires amendments to training continuums and time
		There is no service training spectrum for Work Health Safety Manual Level 2 Occupational Hygiene. The ADF EOH workforce is predominately at the Level 1 Technician. The limited number of ADF Level 2 practitioners completed this study via the Defence Assistance Study Scheme (predominately Air Force Environmental Health)

Table 4. Panel Discussion 4: Health surveillance informing health intelligence=

Panel Focus	Fundamental Input to Capability	Key Points
Improving health surveillance to inform health intelligence	Doctrine	There is a current gap in joint and service policy specifying how health surveillance information collection at the tactical level informs operational and strategic health intelligence products and the follow-on feedback loop. ADF Health Manual Volume 20 - Preventive Medicine would be the appropriate document to clarify the process
	Doctrine/ Materiel	Developing an MOU among the five-eyes community to leverage existing laboratory capability could standardise environmental and occupational hygiene sample collection, analysis, risk reporting, data repository, and inform future health intelligence products
	Major systems	The US Army Military Exposure Surveillance Library (MESL) is a system designed to facilitate the capture and collection of environmental sampling data (contains over 65,000 files) using standardised forms and methods. It is accessible (data push and pull) by the Australian, Canadian, United Kingdom, United States and New Zealand military (AUSCANUKUS+NZ) partners and could be leveraged to fill current ADF health surveillance data collection/repository gaps
	Major systems/ Doctrine/ Support/ Organisation	The US Army maintains a laboratory in Japan capable of environmental and occupational hygiene sample confirmatory analysis. Could a formal Memorandum of Understanding between the AUSCANUKUS+NZ group facilitate the use of this level 5 laboratory reach back capability for operations in the Pacific on a fee for service basis? Should the ADF expand the Defence Support and Reform Group standing offer panel to include a certified civilian lab? Could the mission of the ADF Army Malaria Institute be expanded to fill this gap?

In addition to the conference presentations, a formal dinner and awards ceremony was held where three Defence members were recognised for their distinguished service. CPL Ken Breen, Preventive Medicine Technician, 1st Preventive Medicine Company, received the EOH Deployment Award for expertly providing preventive medicine support on six different exercises and operations within Australia as well as Papua New Guinea over the previous 12 months. FLTLT Sean Walden, OIC Environmental Health Royal Malaysia Air Force Butterworth Health Clinic, was awarded the EOH Garrison Award for providing superior EOH support to personnel assigned to the base as well as the numerous units rotating through the region on recurring exercises. LTCOL Paul Byleveld, Specialist Reserve, 3 Health Support Battalion, received the ADF EOH Lifetime Achievement Award for his expertise in water and sanitation while serving the ADF, NSW Health Department, and other international relief organisations over the past 25 years.

Image 1 (L to R: LTCOL Byleveld, COL Brennan (Dinner Guest Speaker), CPL Breen, FLTLT Walden)

Conclusion

Despite these individual and other organisational successes, some of the issues highlighted during the panel discussions were identified eleven years ago when the community of interest met at their last conference. A few new issues have emerged since this time. What was reassuring to the audience assembled is the motivation to find common solutions to common problems, not only within the ADF, but amongst the broader international community. Senior leaders recognise the need to properly resource the profession in order to meet their mission mandates. Individuals within the EOH trade recognise the need to define their competencies and improve efficiencies in how they provide support both in the garrison and deployed environments. All participants see potential in formalising EOH relationships with partner nation Defence forces via established Memorandums of Understanding, especially in the area of health surveillance and laboratory analysis that informs health intelligence. Through this combination of near term efficiencies, mid-term resourcing, and long-term partnerships, the community remains confident progress will be made on many of the key issues identified in 2015 and looks forward to sharing these successes during the 5th ADF EOH Conference to be held in 2017.

Corresponding author: Derek Licina
Email licinadj@gwmail.gwu.edu
Authors: D. Licina[1], A. Brittain[1], A. Tout[2], T. Strickland[3], D. Taplin[4]
Author Affiliations: [1]Joint Health Command - Directorate of Military Medicine
[2] Army - Preventive Medicine Company
[3] Air Force - Expeditionary Health Squadron
[4] Air Force - Air Force Safety

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Malariology in Australia between the First and Second World Wars (Part 2 of 'Pioneers of Australian military malariology')

Ian Howie-Willis

Abstract

Two 'push' factors drove Australian malariological research in the decades before World War II. The first was the nation's own experience of malaria in its tropical north, where local, usually seasonal, outbreaks of the disease occurred fairly regularly. The second was the Army's experience of malaria during overseas deployments.

During the two inter-war decades, the 1920s and 30s, Australian research into tropical diseases generally and malariology in particular benefited from the return to civilian life of former Australian Army Medical Corps (AAMC) medical officers who had seen malaria at first hand during World War I. A small but significant number of them specialised in tropical medicine post-war in either the specialist medical research institutes or university medical faculties. As the war ended they began publishing their findings. This corpus of research reports was the 'soil' from which Australian malariology grew.

Introduction

Part 1 in this series of articles, 'Pioneers of Australian military malariology', profiled the careers of five AAMC officers and one civilian tropical diseases specialist who had direct experience of malaria during the first two decades of the twentieth century. In the Australian Army, malaria had been diagnosed among troops of successive contingents sent to South Africa during the Boer War of 1899–1902. The Army suffered its first two epidemics of the disease during the next war, World War I, in New Guinea in 1914–15 and in Syria in 1918.

Part 2 in the series now examines the next two decades, the inter-war period, when tropical medicine emerged as a separate field of specialisation in Australian medical science. As in Part 1, the frame of reference is biographical. Part 2 will profile a group of former AAMC officers who either published reports on their experience of malaria during World War I or, specialising in tropical diseases, carried Australian malariology further during the 1920s and 30s.

In great contrast to World War I and later World War II, the AAMC undertook no anti-malarial work of any kind during the two interwar decades. There were three main reasons for this:

- The AAMC had no staff for research because its commander, the Army's Director General of Medical Services (DGMS) was the only full-time staff member.
- Except for the DGMS, all the AAMC medical officers were members of the reserve forces; and so their soldiering had to be fitted into their spare time in their busy professional lives.
- Malariology was the province of several organisations specialising in tropical medicine, most notably the Australian Institute of Tropical Medicine in Townsville and later (from 1930) the School of Public Health and Tropical Medicine at the University of Sydney.

Despite that, various Army- and war-related research papers and a book about malaria were published in Australia between the two World Wars by veterans of the World War I campaigns against malaria. Further, the Army's experience of malaria during World War I helped shape Australian knowledge of the disease and consequently helped prepare the AAMC for its struggles against the disease during World War II.

The 1920s: malaria reportage in *The Medical Journal of Australia*

The material published on malaria during the inter-war decades included most notably what appeared in the chapters by Rupert M. Downes, F. Arthur Maguire and Raphael W. ('Ray') Cilento in the first volume of A. Graham Butler's official Australian medical history of World War I, *The Australian Army Medical Services in the War of 1914–1918*. These chapters were referred to in Part 1 of this series.

In addition to Butler's encyclopaedic work, various papers by former AAMC medical officers were published in the *Medical Journal of Australia (MJA)* during the 1920s.

The first of the *MJA* articles was by Colonel Robert Fowler (1888–1965), who went on to a distinguished career as a gynaecological surgeon and medical statistician.[1] His article 'The risk of malaria in Australia' appeared in the *MJA* in August 1919.[2] The second, 'Incidence of malaria amongst troops on a transport to Australia from Egypt and Palestine', was written by Colonel Walter Ernest Isaac Summons (1881–1970).[3] It was published in the same *MJA* edition as Fowler's article.[4] Both articles alerted the medical profession in Australia to the likelihood that troops repatriated from the Middle East would have returned home with malarial infections and could become malaria carriers in Australia.

The Commander of Anzac Division Medical Services, Colonel Rupert Downes (centre, front row) and his staff, which comprised medical officers of both the AAMC and the Royal Army Medical Corps, Palestine, 1917. Colonel Robert Fowler (inset) is sitting at the left. (Australian War Memorial [AWM] photograph no. H02522.)

'In the near future,' Fowler wrote, 'practitioners will be called upon to treat a considerable number of malarial recurrences in men discharged from the Australian Imperial Force (AIF), many of which will be malignant, and therefore liable to be rapidly fatal.'[5] By thus opining, Fowler demonstrated the limited knowledge of the era. At the time the medical profession insufficiently recognised that 'malignant' malaria, i.e. the *falciparum* form of the disease, did not recur because it has no dormant phase in the liver as does the *vivax* ('benign') form of the disease. Fowler went on to opine that 'unless prevented, there will be widespread infection of Australian anopheline mosquitoes, with both benign and malignant parasites and a consequent increase [in malaria cases] in endemic areas'.[6]

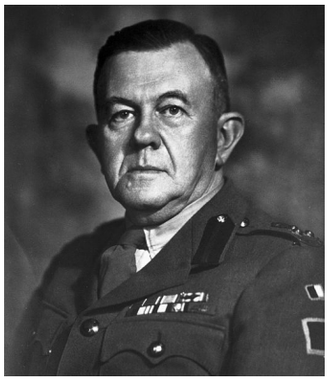
A third *MJA* article was by Major Wilfred Evans MC (1889–1958). Evans had briefly served as the 'Principal Medical Officer (PMO) of Damascus' with the Desert Mounted Corps during the catastrophic malaria epidemic in Syria during October 1918. (The epidemic was described in Part 1 in the series.) Evans's article, 'Anti-malarial work with the Australian Mounted Division in Palestine, which appeared in the *MJA* in December 1919, summarised the anti-malarial effort in the lower Jordan valley during the summer of 1918.[7]

Major Wilfred Evans MC, who served as the Principal Medical Officer of Damascus with the Desert Mounted Corps during the malaria epidemic in Syria during October 1918. (Australian War Memorial photograph no. H00034.)

The articles by Fowler, by Summons and by Evans were the first of a series of articles and reports trickling into the *MJA* from the wartime experiences of AAMC officers who had treated malaria and other tropical diseases. Among these was an item by an officer who would lead the AAMC's anti-malarial effort during World War II — Lieutenant-Colonel (later Brigadier Sir) Neil Hamilton Fairley.[8] During his service in the 14th Australian General Hospital (AGH) at Abbassia in Egypt, Fairley had made a special study of bilharziasis (schistosomiasis), which he had reported in the *Journal of the Royal Army Medical Corps* in April 1919.[9] The *MJA* duly drew attention to this achievement.

Colonel Walter E.I. Summons, who commanded the 14th AGH at Abbassia near Cairo. He treated many of the malaria victims evacuated from Palestine and Syria during 1918. (AWM photograph no. B00661.)

Each of the four AAMC officers just mentioned had served with distinction in the Middle East during World War I. Both Fowler and Evans were in the Desert Mounted Corps. Fowler was awarded a military OBE and was mentioned in despatches three times. Evans also received three mentions in despatches as well as the Military Cross. Summons, who had served in both the Middle East and in France, ended the war as the commandant of the 14th AGH at Abbassia. He was mentioned in despatches and awarded the OBE.



Colonel (later Brigadier Sir) Neil Hamilton Fairley as the Director of Medicine, Allied Land Forces Headquarters, Melbourne, about 1943. (Wikimedia photograph.)

Fairley, who will be profiled in detail in a later article in this series, worked at the 14th AGH at Abbassia, where he became the senior physician and made special studies of dysentery, typhus and malaria. He became interested in tropical medicine as a specialty under the influence of Lieutenant-Colonel (later Sir) Charles James Martin (1866–1955),[10] with whom he worked in the Anzac Field Laboratory. In August 1916 Martin had established the Anzac Field Laboratory. (As described in Part 1 of this series, the Laboratory provided an indispensable pathological testing service for the AIF in the Middle East during the desert campaigns of 1916–1918.) Fairley, too, was mentioned in despatches and awarded the OBE.[11] Fowler, Evans, Summons and Fairley later served again with the AAMC during World War II.

Fairley would become a truly pivotal figure in international malariology. A prolific author of papers on malaria, he would become one of the great heroes of the Australian Army's struggle against the disease. At the end of World War I he spent two years working with his Anzac Field Laboratory mentor, Charles Martin, at the Lister Institute of Preventive Medicine in London. While there he earned a diploma in tropical health and hygiene from Cambridge University before returning to Melbourne in 1920 to an appointment at the Walter and Eliza Hall Institute of Medical Research.[12]

Before returning to Australia Fairley produced a paper on the mortality from malignant (*falciparum*) malaria among the Allied and enemy forces in Palestine during the war. He and his co-author, a Captain H.R. Dew of the Royal Army Medical Corps (RAMC), presented their findings to a meeting in London of the Royal Society of Tropical Medicine and Hygiene (RSTMH). The RSTMH, of which Fairley would later serve a two-year term as president (1951–53), subsequently published the paper in its quarterly journal *Transactions of the Royal Society of Tropical Medicine and Hygiene*. The paper, which had the title 'The causes of death from malaria in Palestine — A study in cellular pathology',[13] was the first of 20 on various topics that Fairley would publish in *Transactions* between 1920 and 1952, the year he was elected as a Fellow of the Royal Society of London for Improving Natural Knowledge, commonly known as simply the Royal Society. The 'FRS' (Fellow of the Royal Society) postnominals are arguably the most prestigious of all for a scientist. In Fairley's case they would earned largely for the research he published in the *Transactions*.

Fairley's and Dew's London presentation to the RSTMH reported their findings after their post-mortem examination of blood slides from 80 wartime victims of *falciparum* malaria in Palestine. In preparing their study they had received assistance from two AAMC officers, Lieutenant-Colonel C.B. Blackburn[14] and Colonel W.E.I. Summons, each of whom is briefly discussed elsewhere in this article.[15]

Of the 80 malaria victims whose deaths Fairley and Dew investigated, 47 were Turkish prisoners, 22 were British and Australian soldiers and 11 were Egyptians from the Egyptian Labour Corps. Only 13 (16 per cent) of the victims had died from 'uncomplicated' malaria, i.e. malaria alone. The rest had died from malaria complicated by secondary infections which were largely from the simultaneous influenza pandemic. Multiple infectious agents do interact; and *falciparum* malaria and influenza were shown to be a particularly lethal combination in the Egypt-Palestine region on the basis of Fairley's and Dew's work. Their research was confirmed by other RAMC officers who had worked in the Salonika–Macedonia (modern Greece) and Mesopotamia (modern Iraq) theatres of the war.[16]

In 1920 soon after returning to Melbourne, Fairley presented a second paper on the subject of the recent malaria epidemics among the troops in Palestine. It was titled 'Observations on the clinical and applied pathology of malaria' and was delivered to the Australasian Medical Congress in Brisbane.[17] Fairley's paper provoked a lively discussion among the members of his audience, some of whom had

been wartime AAMC officers. They included Major Eustace W. Ferguson and Lieutenant-Colonel (later Sir) Charles Bickerton Blackburn (1874–1972).[18]

During the early 1920s the *MJA* continued publishing material relating to the Army's recent experience of malaria. Among the more prominent authors of *MJA* articles was Major Eustace William Ferguson (1884–1927), a pathologist and entomologist who had worked in military hospitals in England, France and Egypt before commanding the Anzac Field Laboratory between August 1918 and March 1919. Major Ferguson had accordingly led the Anzac Field Laboratory through the malaria epidemics in Amman and Damascus during September and October 1918. In a paper to the Australasian Medical Congress in 1920 he outlined the malarial diagnostic work done by the Anzac Field Laboratory and the malaria diagnostic stations during these epidemics. In the post-war years Ferguson became the principal microbiologist in the New South Wales Department of Health. His interests were broad but he was particularly interested in dengue fever and malaria and their links with medical entomology. He published numerous research papers on Australia's fleas, ticks, biting flies and mosquitoes before his early death from nephritis at the age of 42.[19]

Major Eustace W. Ferguson making a microscopical examination in the pathology department of the 3rd AGH at Abbeville, France, June 1918. Ferguson later commanded the Anzac Field Laboratory in Palestine and Syria. (AWM photograph no. E02603.)

Major Eustace W. Ferguson and staff of the Anzac Field Laboratory, Aleppo, Syria, 1918. Ferguson is sitting, centre of front row. (AWM photograph no. B01025.)

Immediately after Ferguson's presentation to the 1920 Australasian Medical Congress there came a second paper on the wartime anti-malarial work done in Palestine and Syria. This was presented by Harvey Sutton (1882–1963), who had served as an AAMC captain in the AIF in Egypt and then in the campaigns in Sinai, Palestine and Syria. He had commanded the No. 7 Sanitary Section of the Anzac Mounted Division and then worked with Ferguson in the Anzac Field Laboratory.[20] Promoted to major in 1918, Sutton served as the Deputy Assistant Director of Medical Services (DADMS) at AIF headquarters in Cairo. He was mentioned in despatches twice and awarded the OBE. After the war Sutton specialised in public health; and when the Commonwealth government and the University of Sydney established the School of Public Health and Tropical Medicine in 1930, Sutton became the school's first director and the foundation professor of preventive medicine. As such, he retained an interest in the diagnosis of and prophylaxis against malaria. During World War II the Sydney School would play an important part in providing advice and training for the armed services in tropical medicine, while Sutton himself, promoted to lieutenant-colonel, became an inspector of army camps.

Professor Harvey Sutton, Director of the School of Public Health and Tropical Medicine at the University of Sydney, 1935. (National Library of Australia photograph no. nla. pic-vn4506408.)

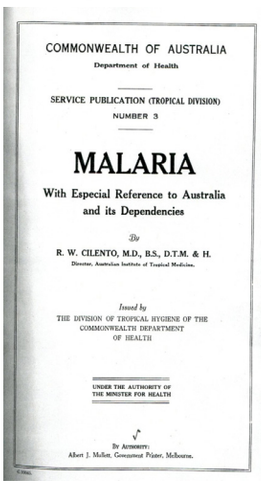
Lieutenant-Colonel Charles Bickerton Blackburn had helped Fairley with the research for the paper he had presented to the RSTMH in London with Captain Dew. Blackburn had served with distinction during the war. He had worked with Fairley at the 14th AGH at Abbassia, was mentioned in despatches twice and awarded the OBE for his wartime service. A leading figure in Australian medical politics, he later served a term as Dean of Medicine at the University of Sydney, where he was also a long-serving Chancellor 1941–64.

Sir Charles Bickerton Blackburn, an AAMC lieutenant-colonel in both World Wars I and II. (National Library of Australia photograph no. vn4193824-v.)

Although aged 65 when World War II began, Blackburn enlisted in the Army and subsequently saw service as a lieutenant-colonel at the 113th AGH at Concord. His son, Charles Ruthven Bickerton Blackburn (1913–), a physician, served with the 5th AGH in the Middle East and New Guinea during World War II. A lieutenant-colonel, he later commanded the Land Headquarters Medical Research Unit in Cairns — the unit responsible for leading the Army's campaign against malaria 1943–46.[21] We will meet Blackburn Jnr. again in the latter guise in a later article in this series.

An Australian 'first' — R.W. Cilento's book *Malaria*

During the early 1920s Dr Raphael West Cilento (1893–1985) emerged as one of the leading figures in Australian malariology.[22] Part 1 in this series profiled Cilento in detail. It pointed out how he wrote the first Australian book on malaria. This was Malaria, with special reference to *Australia and its Dependencies*, published by the Tropical Division of the Commonwealth Department of Health in 1924.[23]



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MALARIA
With Especial Reference to Australia and its Dependencies

By
R. W. CILENTO, M.D., B.S., D.T.M. & H.
Director, Australian Institute of Tropical Medicine.

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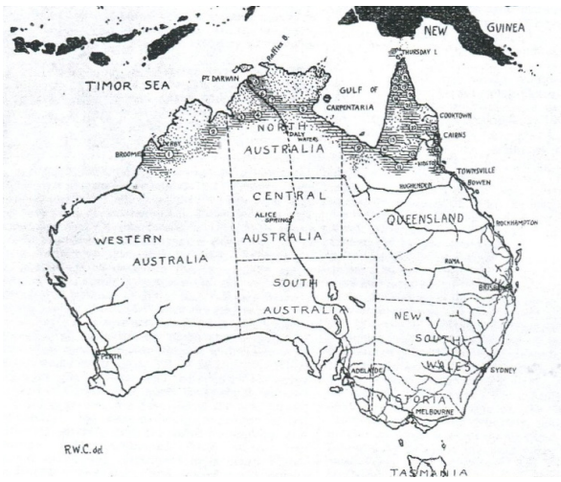
An Australian 'first': the title page of R.W. Cilento's 1924 book on malaria.

Before he published his *Malaria*, Cilento gave a preview of his approach to the disease in a presentation to the Australasian Medical Congress in 1923. This was essentially epidemiological. Thus, he observed that the malarious zone in Australia extended north from Ingham (100 kilometres north-west of Townsville), encompassing Cape York Peninsula and then west across the 'Top End' of the Northern Territory, where it extended south to the Roper River (380 kilometres south-east of Darwin), and then south-west into Western Australia to the Fitzroy River mouth near Derby and beyond that to south of Broome (160 kilometres south-west of Derby).[24] The vector, he said, was 'probably *Anopheles annulipes* or *Anopheles bancrofti*'; but he believed the culprit was most likely the former because 'it was the only common mosquito in the regions where malaria was found and in some localities, for example on the Roper River, it existed in enormous quantities and was the sole species found'.[25]



R.W. Cilento's map of the distribution of malaria in Australia and the adjacent archipelagos. As the map indicates, the malarious zone extends from Townsville, across Cape York Peninsula, along the Gulf of Carpentaria, across Arnhemland and through northern Western Australia to Broome. Cilento feared that the extension of the railway networks in northern Australia (marked on the map) would facilitate the rapid spread of malaria beyond the malarious zone. (Source: R.W. Cilento and A.H. Baldwin, 'Malaria in Australia' in The Medical Journal of Australia, 1 March 1930, p. 274.)

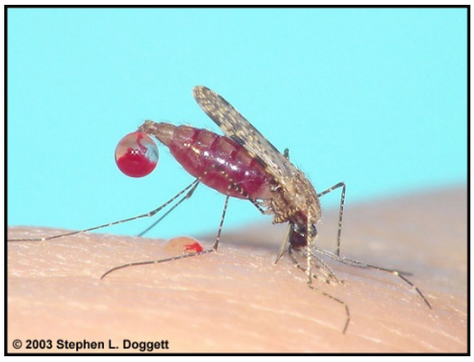
Cilento also expressed fears that the extension of the railway networks in northern Australia might help to spread malaria. If malaria carriers became more mobile they could carry the disease into southern regions among non-infected populations. As things turned out, the fear of malaria moving elsewhere, as dengue fever had already done from Queensland into New South Wales, was probably exaggerated. For the

disease to spread further south, large congregations of malaria carriers moving into the southern regions would have been necessary, but that did not occur.

What did occur sometimes was that itinerant miners returning from New Guinea brought malaria with them, as in 1910 in the mining camp at Kidston, inland from Townsville. Infected miners from the Papuan diggings settled in Kidston in sufficient numbers to constitute a concentration of malaria carriers which then became the source of infection for the local community in an outbreak of the disease. In a population of about 400 at Kidston, 120 people suffered malaria, of whom 'at least 25 died'.[26]

Although there was no southward extension of the malaria zone, as Cilento feared, his concern was justified. The mosquito he identified as the culprit, *Anopheles annulipes*, has a widespread distribution in Australia, not just in the northern tropical malarious zone but in the temperate southern States as well. It occurs throughout New South Wales and Victoria and is widespread in South Australia and lowland areas of Tasmania. As a malaria vector, this species of mosquito 'has been responsible for the transmission of [the disease] in many areas of southern Australia'.[27] It is also a vector for human filaria (the threadlike worms causing the disease filariasis), for Ross River virus (which causes epidemic polyarthritis) and for canine heartworm.[28]

Cilento's *Malaria* received an enthusiastic review in the *Medical Journal of Australia*. The author, the *MJA* averred, 'is to be congratulated on the thoroughness with which he has compiled this work and on the judgement and knowledge he has displayed in handling a very large subject'.[29] The book comprised four sections. The first was a general introduction to the history, causes and worldwide distribution of malaria. The second dealt with the human pathology of the disease, its symptoms, complications and treatment. The third summarised the various means for controlling the mosquito vectors and for taking prophylactic measures to prevent malarial infection. The fourth section was an entomological summary of Australia's mosquitoes, with an emphasis on the anopheline transmitters of malaria. 'The usefulness of this publication and the skill displayed by the author in its compilation remain unchallenged,' the reviewer asserted, before concluding that 'from the point of view of the tropical hygienist the [book] deserves nothing but praise'.[30]



Anopheles annulipes: a malaria vector with wide-spread distribution in Australia. This particular female mosquito has become so engorged in taking her blood meal she has begun exuding a globule of blood from her anus. (Photograph by Stephen L. Doggett, from the website of the New South Wales Arbovirus & Vector Monitoring Program of New South Wales Health'; reproduced with the photographer's kind permission.)

During the year in which his book was published, 1924, Cilento returned to Rabaul as the Director of Health in the Australian administration of the Mandated Territory of New Guinea, formerly German New Guinea. He held the position for four years on secondment from the Australian Institute of Tropical Medicine (AITM). Cilento continued his study of malaria in New Guinea and published several more papers on the subject. After accepting a position in Brisbane as the Commonwealth government's Director of Tropical Hygiene and Chief Quarantine Officer for north-east Australia in 1928, his malariological career effectively ended.

Cilento's last foray into malariology was a long article in the *MJA* in 1930 jointly written with Alec Hutcheson Baldwin (1891–1971),[31] who from 1924 had been his successor at the AITM, as Acting Director. It was an authoritative paper tracing the history and the distribution of malaria in Australia. It charted the progressive decline in the incidence of the disease in Australia to the point where the annual death rate was only five deaths per million of population by 1929.[32]

Cilento and Baldwin attributed the decline to several factors. First, there was no large malaria-infected indigenous population to form a reservoir of infection, as there was across the Torres Strait in Papua and New Guinea; and in any case, Australia's indigenous population was diminishing. Second, Australia's malarious zone was sparsely populated. Third, was the action of government health agencies and especially the Commonwealth Department of Health in monitoring the occurrence of malaria and in acting quickly to manage outbreaks of the disease. Finally, and most importantly, increasingly

high living standards in Australia had resulted in the populations of malarious regions being able to adopt and afford anti-malarial protective measures. In this connection they quoted the Scottish malariologist, Sir Malcolm Watson (1873–1955), who had observed that 'the poor are malarious and the malarious poor'.[33]

Cilento's and Baldwin's statistics could not tell the whole story of the decline in mortality from malaria in Australia because they had only the figures from 1905 to 1927. In the present era, with more than a century of figures on deaths from the disease, a more complete picture emerges. This is summarised in the following table, which relates malaria mortality to population for the century between 1905 and 2005. As the table demonstrates, the decline was both absolute and relative. From 55 malaria deaths in 1905, the number fell to just 10 a century later; and most of those ten were almost certainly individuals who had contracted the disease overseas. Expressed as a rate, 'deaths per million of population', the decline was from 13.75 deaths per million in 1905 to 0.49 deaths per million in 2005 — a reduction by a factor of 28 over a period when the Australian population quintupled from four to twenty million.

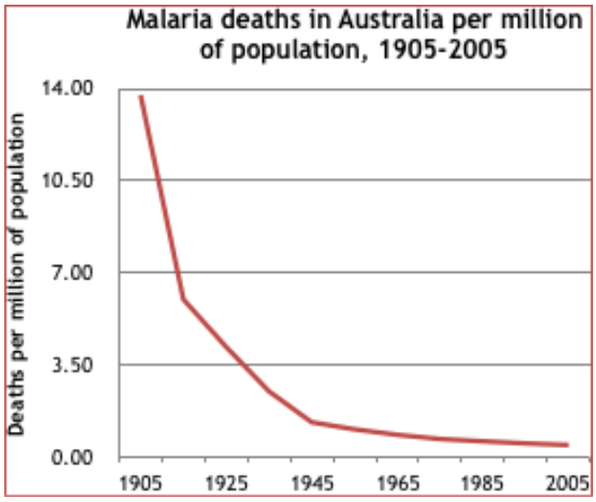
Deaths from malaria in Australia, 1905–2005

Year	Australian population (millions)	Total deaths from malaria	Malaria deaths as rate per million of population:
1905	4.00	55	13.75
1915	4.99	30	6.01
1925	5.94	25	4.21
1935	6.73	17	2.53
1945	7.39	10	1.35
1955	9.20	10	1.09
1965	11.39	10	0.88
1975	13.90	10	0.72
1985	15.79	10	0.63
1995	18.05	10	0.55
2005	20.33	10	0.49

Source: Official Yearbooks of the Commonwealth of Australia, the tables showing causes of deaths.

When the falling mortality rate is graphed, as below, the decline is seen to be spectacular. As mortality from malaria was falling, Australian living standards were rising, public health programs were reducing transmissible diseases to very low levels of incidence and the local pool of the malaria-infected had evaporated.

In the post-World War II decades the deaths that did occur in Australia from malaria would almost certainly have been among travellers from nearby malarious countries — Papua New Guinea, for instance — returning home to Australia after falling ill with the disease. Fewer needed to do so as the turn of the millennium approached because improved medical care in the countries Australians visited had lowered the risk of malaria for them when travelling abroad.[34]



Australia's declining mortality from malaria: the deaths from malaria in Australia over the century 1905–2005.

Cilento's co-author in 1930, Alec Baldwin, also had a distinguished career in tropical medicine and health. He enlisted in the AAMC on graduating in medicine from the University of Melbourne in 1917 then served as a captain with the 5th Field Ambulance on the Western Front until the end of the war. After the war he remained in England, working in the Birmingham Children's Hospital and earning a diploma in public health and later a diploma in tropical medicine and hygiene. He then worked at Rabaul and in 1924 followed Cilento's as the Acting Director of the AITM. When the AITM merged with the new School of Public Health and Tropical Medicine at the University of Sydney in 1930, Baldwin moved to Sydney and became the school's Deputy Director under Professor Harvey Sutton. After World War II, as Professor Baldwin he also held the school's chair in tropical medicine until his retirement in 1956.

During the war he had served with the RAAF as the director of hygiene and tropical health from 1943 as a group captain, a rank equivalent to that of army colonel.[35]

As the foregoing biographical profiles suggest, the Australian Army's experience of malaria and other tropical diseases during World War I greatly stimulated interest in tropical medicine in Australia. Following their wartime duties with the AAMC, a small but influential group of medical officers chose to specialise in this field on quitting the AIF and several specialised in malariology. They acquired their postgraduate qualifications and experience at universities and research institutes in England and then returned home to take up positions in the newly established Australian medical research institutes and the universities. They presented their research findings to the meetings of the Australasian Medical Congress. The *Medical Journal of Australia* then reported the congress discussions and published their papers. This sequence was a major influence in keeping the medical profession in Australia informed about tropical diseases.

In relation to malaria in particular, the *MJA* published a continuing flow of articles, news items, editorial comment, letters and book reviews. During the two inter-war decades, the *MJA* ran 85 separate items on malaria. Many of these reflected on Australian advances in malariology; others reported overseas developments in the discipline. By the time World War II began, any medical practitioner who regularly read the *MJA* would have been reasonably well informed about the disease. Thanks to the efforts of Fairley, Cilento and their World War I AAMC colleagues who had specialised in tropical medicine, the medical officers who subsequently enlisted in the 2nd AIF were well prepared for tackling malaria, even if not yet ready to face the epidemics of the disease that beset Australian service personnel in Papua and New Guinea in 1942 and 1943.

The 1930s: depression and a stalling of the anti-malarial effort

During the 1930s Australian research on malaria stalled. The great worldwide financial depression which began in 1929 prompted wholesale reductions in public expenditure. The resultant cut-backs in tropical medicine programs were severe. The Commonwealth Department of Health, which had been established in 1921with Dr J.H.L.Cumpston (1880–1954)[36] as its Director-General, was forced to close its Division of Tropical Hygiene in 1930. The division had been formed in 1922, had taken responsibility for the Australian Institute of Tropical Medicine (AITM) in Townsville in 1924 and had conducted enterprising research on hookworm, malaria and filariasis in northern Australia and New Guinea. Largely as a result of the Commonwealth government's harsh measures to reduce depression-era expenditure, the AITM was effectively closed. Its Townsville operations ceased when it was relocated to Sydney in 1930 and merged into the new School of Public Health and Tropical Medicine of the University of Sydney.[37]

The new school was jointly controlled by the university and Cumpston's Department of Health. The AITM name had disappeared, however; and the inclusion of the phrase 'Public Health' in the school's title suggested a broader field of interests than tropical medicine alone. Those who might have hoped for a continuing sharp focus on malaria research — as at the AITM under Raphael Cilento and his predecessor, Anton Breinl — might have been disappointed that teaching would be as much a priority as research.

Perhaps Cumpston grieved privately over the demise of the AITM. Possibly, too, he opted for the pragmatic alternative by superintending its absorption within the School of Public Health and Tropical Medicine in Sydney. His daughter Margaret Spencer, a malaria historian, later wrote that he had narrowly averted the 'extinction' of his whole department amidst the budgetary stringencies of the early 1930s.[38] In such circumstances he possibly saw the merging of the AITM into the Sydney School as the 'least worst' outcome.

In forcing these changes upon Cumpston, the cost-cutting politicians and their minions in the Commonwealth Treasury might not have acted with eyes open to public health futures. If so, they could not have foreseen the malaria epidemics that broke out and claimed lives across Australia's northern malaria zone during the mid- to late 1930s.[39]

During 1934 a series of widespread outbreaks of malaria in northern Australia revealed the need for concerted national effort against the disease. An epidemic of *vivax* malaria in the Torres Strait Islands in June that year resulted in almost a thousand (987) notifications of the disease. There were other outbreaks that year elsewhere in Queensland as well as in the Northern Territory and Western Australia. Serious outbreaks of *falciparum* malaria occurred in both the Victoria River and Wave Hill districts of the Northern Territory. In 1934, too, *falciparum* malaria was discovered in Western Australia for the first time.[40]

Despite the downward trend of the graph for malaria mortality seen above, the total number of deaths from the disease in Australia between 1934 and 1939 was 96. During the next six-year period, 1940–

45, there were only 60 deaths.[41] Those 60, however, occurred during the wartime period of catastrophic malaria epidemics in Papua and New Guinea. During that time many of the infected troops were being repatriated to Australia for treatment, thus serving to inflate the mortality figures.

In retrospect we can appreciate that a co-ordinated approach to malaria might have prevented the outbreaks of the disease suffered during the mid-1930s. Co-operation between the Commonwealth and the various State public health authorities in public health emergencies was a federal ideal, but the constraints of depression-era budgets precluded its realisation during the 1930s.

What the outbreaks of the 1930s might have cost the Commonwealth and States financially is probably unknowable. We might nevertheless speculate that the aggregate public cost of all the medical investigations and examinations, hospitalisations, courses of treatment, convalescent care and invalid pensions was substantial. We might also conjecture that the cost far exceeded the expenditure that would have been required to retain the AITM in Townsville in its original form. We might even infer that timely advice from the AITM to the public health authorities could have prevented or at least have minimised the impact of the epidemics.

Ironically, almost six decades after the closure of the AITM, an organisation that saw itself as the AITM's successor was established in Townsville. This was the Anton Breinl Centre for Public Health and Tropical Medicine of the James Cook University. This centre was founded in 1987 in the original AITM building. It also became the base for a new professional organisation, the Australasian College of Tropical Medicine.

Administrative and institutional historians are able to take a long-term view of events like the disappearance of the AITM and the establishment of organisations fulfilling similar functions in its former premises 58 years later. They recognise that what penny-pinching politicians and bureaucrats 'rationalise' in one generation others must recreate in another, often at much greater expense.

Historians also know that government agencies such as the AITM, the Commonwealth Department of Health and the Australian Army Malaria Institute are brought into being because they fulfil key functions and provide essential services in modern societies. They may be reorganised and also terminated, their functions split away and assigned to other institutions. The latter options, however, are not necessarily more cost-effective, administratively efficient or productive of better research outcomes. The perceived savings in financial, material and human resources may prove to be illusory.

Reverting now to the establishment of the School of Public Health and Tropical Medicine in 1930, the school started well despite the severe financial restrictions of the era. It began teaching courses in tropical medicine and hygiene and undertook mosquito survey work in New Guinea. In 1935 the school sent a medical expedition to Papua at the request of the territory's Australian administration. The expedition conducted malaria surveys among the Goilala, Roro and Mekeo peoples of the Port Moresby hinterland. It found that *falciparum* malaria was 'hyperendemic' among the Mekeo, with all children between two and five years of age having enlarged spleens — a reliable indicator of a community's exposure to malaria. The expedition members experimentally used the anti-malarial drug atebrine among the Mekeo and found it to be effective in treating malaria attacks.[42]

A second expedition from the school worked in Papua during 1938–39, again at the invitation of the Papuan administration. Its task was to investigate population decline among the island groups in the Milne Bay District of eastern Papua. One of the expedition members was Dr (later Sir) Edward William Spencer ('Ted') Ford (1902–86), who as an AAMC lieutenant-colonel would soon become a key figure in the Australian Army's great struggle against malaria in Papua and New Guinea during World War II.[43] A later article in this series will profile Ford, demonstrating his enormous contribution to the development of Australian malariology generally and of military malariology in particular.

Internationally as well as in Australia the great depression of the 1930s impeded malaria research and anti-malarial programs. The Health Committee of the League of Nations, for example, had aimed to eliminate leprosy, malaria and yellow fever but the forced economies of the 1930s restricted its achievement. Politics also played its part because the Health Committee's Malaria Commission was compromised by its own internal divisions. The commission began by reporting on malaria control measures in the League's member nations in 1924. Its report emphasised the point that raising living standards in malarious nations would be an important step towards eliminating the disease. Thereafter, however, the commission was beset by internal factional disagreements over the best means for controlling malaria. On the one hand were the proponents of mosquito control; and on the other hand were the advocates of 'quininisation' — ridding human hosts of malarial parasites by dosing them with quinine.[45]

Meanwhile, the US-based Rockefeller Foundation had been promoting and funding mosquito control and malaria eradication projects enthusiastically. During the 1930s its projects in China and Brazil enjoyed some successes.[46] The League of Nations Malaria Commission was sceptical of claims the foundation made about its successes elsewhere, however. In one instance in 1927 the US Surgeon General pressured the League into withholding from publication a commission report expressing doubts about the scientific rigor of the Rockefeller-sponsored projects. This controversy revealed rivalries between the European and American malariologists. The former supported the Malaria Commission while the latter sided with the Rockefeller Foundation. Although the USA never joined the League of Nations, this episode demonstrated that the US scientific 'Establishment' was powerful enough to influence the League's health policies.[47]

With conflicts like these besetting malariology on the world stage, the side-show of depression-era Australian malariology remained just that. Apart from a handful of medically trained individuals at the School of Public Health and Tropical Medicine in Sydney, few Australians specialised in malariology. The best of those who did, most notably Neil Hamilton Fairley, had to seek their study and employment opportunities overseas.

This situation, however, was about to change dramatically. The malaria epidemics suffered by Australian forces fighting the Japanese in Papua and New Guinea during World War II would prompt new, intense malariological research in Australia. Part 3 in this series will show how that happened.

Author's affiliations: Dr Ian Howie-Willis is a professionally trained practising historian who completed his formal historiographical training at the Australian National University, where he wrote a thesis on the development of the university system in Papua New Guinea. His most recent book is An Unending War: The Australia Army's continuing struggle against malaria, 1885–2015 (Big Sky Publications, 2016). Part 1 of his series of articles on 'The pioneers of Australian military malariology' was published in an earlier edition of this journal. His current major research project has the working title 'VD: the Australian Army's historical experience of sexually transmitted diseases'.

Abbreviations

AAMC	Australian Army Medical Corps (prefixed 'Royal' from 1948)
AAMI	Australian Army Malaria Institute
ADB	The Australian Dictionary of Biography
AGH	Australian General Hospital
AIF	Australian Imperial Force
AITM	Australian Institute of Tropical Medicine
ANMEF	Australian Naval and Military Expeditionary Force
AWM	Australian War Memorial
DADMS	Deputy Assistant Director of Medical Services
DDMS	Deputy Director of Medical Services
DGMS	Director General of Medical Services
DMS	Director of Medical Services
FRS	Fellow of the Royal Society
HQ	headquarters
MJA	Medical Journal of Australia
NAA	National Archives of Australia
OBE	Officer of the Order of the British Empire
PMO	Principal Medical Officer
POW	Prisoner of War
RAMC	Royal Army Medical Corps
RSTMH	Royal Society of Tropical Medicine and Hygiene
USA	United States of America

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A Review of Art Therapy Among Military Service Members and Veterans with Post-Traumatic Stress Disorder

Jeremy Ramirez, BS, MPH-C

Introduction

Every day in the United States approximately 22 veterans, and one active duty service member, reservist, or national guardsman commits suicide and the rate is climbing.[1-2] In 2008, there were 197 reported suicides; 2009, 238; 2010, 301; 2011, 283; 2012, 325.[3] In addition to fighting the Global War on Terror, current service members and veterans are left to battle postwar symptoms related to post-traumatic stress disorder, otherwise known as PTSD. As the wars in Iraq and Afghanistan have come to a close, there is growing concern over the efficacy of postwar treatment, which will be needed for the increasing number of veterans returning home. Veterans Affairs (VA) healthcare is the largest healthcare delivery system in the United States and according to a U.S. Congressional Research Service report for Congress, the prevalence of PTSD among Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) veterans receiving VA healthcare in FY2002-2012 was 29%.[4] It is important to note that although combat exposure is a leading cause of PTSD among males, military sexual trauma (MST) is the leading cause of PTSD among females.[5] Although treatment for PTSD is widely researched among past and present military service members, little is known about the potential therapeutic benefits art therapy could offer this population. Existing research indicates that art therapy shows promising treatment results among service members.[6] This project aims to provide a review of why art therapy programs should be implemented among current military service members and veterans diagnosed with PTSD.

Background

According to the American Art Therapy Association, art therapy is the use of artwork to "explore feelings, reconcile emotional conflicts, foster self-awareness, manage behavior and addictions, develop social skills, improve reality orientation, reduce anxiety, and increase self-esteem."[7] The preferred method of treatment for patients with PTSD receiving care in the VA healthcare system is Cognitive-Behavioural Therapy (CBT), however this form of therapy is effective in treating only two of the three hallmark symptom clusters associated with PTSD, i.e., re-experiencing and hyper-vigilance, but not as effective in treating avoidance/ emotional numbing.[8-9] Traumatic events are often difficult to express in words alone, thus art therapy offers a different approach to allow for individual expression. Art therapy, particularly models of art therapy applied in a group setting that offer group feedback, have been shown to be effective in treating patients with PTSD, while specifically focussing on avoidance/ emotional numbing. Art therapy is designed to help participants bridge their memories of past traumatic events in order to understand and communicate their traumatic experience. This may be accomplished using various art activities, including: drawing, painting, and photography. Art therapy aims for participants to share their experience in a healing environment, which ultimately helps improve upon their behavioural and mental health. The following section will provide an overview of PTSD, art therapy sessions and activities, and end with notable mention of art therapy and PTSD outside of the US.

Combat related trauma

Service members in combat theatres of operation, and other potentially hostile military deployment missions (i.e., foreign diplomatic facilities, disaster relief, peace keeping missions, etc.) are vulnerable to many conceivable dangers (i.e., small arms fire, improvised explosive devices (IEDs), rocket propelled grenades (RPGs), mortars, and suicide bombings). These traumatic events are all examples of potential causes leading to the development of PTSD among military service members. Moreover, military service members endure excessive physical exertion, lack of food, sleep, and social support systems, which altogether, further reduce soldiers' health status and quality of life.

Military sexual trauma

In addition to the elements of combat exposure enumerated above, military sexual trauma (MST) is explained at length here due to its especially high prevalence among service members in all of the armed forces. MST is a term adopted by the Department of Veterans Affairs in the early 1990s and is defined as "sexual harassment that is threatening in character or physical assault of a sexual nature that occurred while the victim was in the military, regardless of geographic location of the trauma, gender of the victim, or the relationship to the perpetrator."[10] A number of studies suggest that victims of sexual trauma are just as likely, if not more likely to develop PTSD than service members who have experienced combat exposure.[11-12]

Although females are exceedingly more likely to experience MST than their male counterparts, it is important to note that there are far more males in the military. As of 2010, there were 209,222 females and 1,249,475 males serving on active duty in the military.[13] Consequently, it is no surprise that one study conducted by the VA found that out of nearly 1.7 million patients receiving care from the VA, 22% of females and 1% of males, reported military sexual trauma.[14] Within the VA health care system, females are 20 times more likely than men to have suffered MST, however there are about 20 times more males in the VA health care system. Although females are at greater risk for MST, 54% of patients who screened positive for MST are male.

According to the U.S. Department of Defense in an annual report to Congress, in the 2012 fiscal year there were over 3,300 reported sexual assault incidents among military service members.[15] This number is up from the 2,374 reported sexual assault incidents among military service members in 2005.[16] Sexual assault cases among service members remain far too frequent and warrant greater attention and support against this growing epidemic. Accordingly, the VA continues to uphold MST victim rehabilitation among its top priorities for its enrolled patient population.

PTSD by another name

PTSD has traditionally been classified as an anxiety disorder, however, this classification did not come about until the year 1980 when PTSD first appeared in the third edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-3). Although PTSD was a new phenomenon at the time, PTSD has been known for a long time as a war disorder with different names throughout history. In the Civil War era, PTSD was known as DaCosta's syndrome, by which it was described as a cardiac disorder.[17] In the South African War (1899-1902), British service members were diagnosed with "disordered action of the heart."[18] In the First World War, the prominent label was shell shock, and in the Second World War, battle exhaustion. In Vietnam, it came to be known as combat fatigue, and included symptoms of irritability, panic attacks, and disturbed sleep.[19]

Pathophysiology

PTSD is closely associated with the limbic system, a group of forebrain structures including the hippocampus and amygdala, which primary functions are to govern human emotions.[20] When a person is exposed to a traumatic event they experience a "fight or flight" response, which originates in the sympathetic nervous system. The amygdala in the limbic system activates the SNS in order to produce higher levels of neurotransmitters (i.e., epinephrine, norepinephrine and dopamine). These neurotransmitters are charged with facilitating certain physical reactions, such as: constricting blood vessels, increasing heart rate, and dilating pupils. In addition to signaling the activation of neurotransmitters, the amygdala will communicate this response to the hippocampus, which will then form long-term memories associated with the event.

Clinical symptoms of PTSD

The clinical symptoms of PTSD include a hallmark triad of symptom clusters, including: intrusive recollection (re-experiencing), avoidance/ numbing, and increased arousal (hyper-vigilance).[21] The first symptom cluster, "re-experiencing," includes symptoms of flashbacks, bad dreams, and/ or frightening thoughts.[22] The next symptom cluster, "avoidance/ emotional numbing," includes symptoms of social detachment (i.e., avoiding places, events, or objects that may trigger memories of the traumatic experience). Furthermore, this symptom cluster includes feeling emotionally numb, guilty, depressed, and/ or worried; losing interest in hobbies or activities that were enjoyable in the past; and, having difficulty remembering the traumatic event. The final symptom cluster, "hyper-vigilance," includes being easily startled, feeling anxious, having trouble sleeping, and/or experiencing angry outbursts. Altogether, these symptom clusters serve as a significant barrier to perform the most basic tasks, such as grocery shopping, reading, or sleeping. It is important to note that many of these symptoms are typical following a traumatic event and may last for a short amount of time, which would be acute stress disorder; however, when the symptoms become chronic the individual may then develop PTSD.

PTSD treatment

There are various therapies available for treating PTSD. As noted earlier, the preferred method of treatment for patients with PTSD receiving care in the VA healthcare system is Cognitive-Behavioural Therapy (CBT), which is a form of individualised counselling. The two most common forms of CBT offered at a VA medical centre include: 1) Cognitive Processing Therapy (CPT), and 2) Prolonged Exposure (PE) therapy.

Originally developed for victims of sexual assault, CPT has shown promising treatment results in persons diagnosed with PTSD. The goal in CPT is to help the patient change his/ her outlook regarding their traumatic experience. In CPT a therapist will counsel their patient in identifying and replacing thoughts which cause additional stress, with less distressing thoughts that reduce certain emotions such as guilt, anxiety, and anger. This form of counselling benefits patients by offering a healthier alternative way to think about their past trauma, gaining greater understanding while minimising their avoidance and frustration, which is typically associated with thoughts of which it was previously too difficult for patients to make sense. CPT is composed of four main stages that take place over 12 sessions and last 50-minutes each. The first stage is to educate the patient about PTSD symptoms and treatments. The second stage is to help the patient become more aware of the relationship their thoughts share with emotions. After identifying and isolating negative thoughts, patients learn new skills on how to counter these thoughts with questions. While using worksheets, patients outline how they would like to think and feel about their past trauma. The last stage in CPT is to understand changes in beliefs. For example, trauma victims typically experience changes in how they view trust, self-esteem, and safety. CPT helps patients reconnect with beliefs held prior to their traumatic experience.

The goal of Prolonged Exposure (PE) is to help patients lessen the impact of traumatic memories. Therapists accomplish this through assisting patients in repeatedly visiting their upsetting memories to decrease the fear they have associated with those memories. PE has four main stages and the counselling sessions run 90 minutes in length for 8 to 15 meetings. Similar to CPT, the first stage of PE is to educate the patient on PTSD symptoms and treatments. The second stage is to promote relaxation by training the patient to control their breathing while recalling memories that may cause fear. The third stage is real-world practice, which allows the patient to confront situations they may have been avoiding out of fear related to their traumatic experience. For example, a veteran who has witnessed a suicide bombing in a marketplace may try to visit a grocery store. Likewise, a victim of MST committed by a peer may practise meeting new people and forming relationships with them. The last stage of PE is to practice talking through the trauma. By conversing over the personally held traumatic experience, the patient is able to improve the management of his/ her thoughts and feelings, thus reducing their level of stress.

Mental health issues associated with PTSD

The triad symptom clusters of PTSD often foster a myriad of self-destructive mental health issues, which merit great concern. These mental health issues include the following: depression, aggression, memory loss, substance abuse, alcohol misuse, sleep impairment, sexual dysfunction, social detachment, unemployment, divorce, homelessness, incarceration, suicidal ideation, and possibly, suicide.[23-26] PTSD risk factors for suicide are discussed next.

PTSD Risk Factors for Suicide

In the United States, suicide is the leading cause of non-accidental injury related to death, and in 2009, has accounted for more than 30,000 deaths.[27-28] Suicide committed by veterans accounts for 20 percent of those suicides committed in the U.S.[29] Numerous studies have shown a correlation between PTSD and increased rates of suicide 30.

Homelessness is among the many PTSD risk factors for suicide.[31] Veterans make up one out of every four individuals in the homeless population, and those with PTSD are more likely to experience homelessness.[32] The majority of these veterans completed high school and received an honourable discharge, yet even more veterans struggle to make monthly rent payments which places them at greater risk for homelessness. Although female veteran homelessness is small in comparison to male veteran homelessness (3% vs. 97%), female veteran homelessness exists as a particular area of concern. According to the Substance Abuse and Mental Health Services Administration, when compared with females in the general population, female veterans are four times more likely to experience homelessness.[33]

In addition to homelessness, incarceration stands as another PTSD risk factor associated with suicide.[34] Veterans comprise nearly 10% of the inmate population, and one study has shown that incarcerated veterans are at greater risk for committing suicide when compared to being a veteran or incarcerated alone.[35] Recognising that

there is an association between poor veteran mental health and increased risk for committing criminal offences, special veterans courts have been formed. Although this may be a closer step toward improving the health outcomes for veterans, there remains a greater need for more effective treatment to be made available if the incarcerated veteran population is going to be rehabilitated.

Divorce is another PTSD risk factor for suicide. One study found divorced persons to be at higher risk for suicide than married persons (more than twice as likely).[36] While it is still unclear if military marriages face higher divorce rates than the general population, there is clear evidence of military service members with PTSD experiencing higher rates of divorce than those without PTSD.[37] Kudler found that veterans with PTSD were twice as likely as veterans without PTSD to not only experience divorce, but also experience multiple divorces.[38]

Unemployment is also a significant PTSD risk factor for suicide. In a 20-year prospective study of psychiatric outpatients, unemployment was found to be a significant risk factor for suicide.[39] Smith, Schnurr and Rosenheck found that Vietnam veterans with PTSD were more likely to work either part-time or not at all, and this occurrence became more prevalent as PTSD symptom severity rose.[40] These findings also suggest that even a slight improvement in PTSD symptoms could lead to healthier employment outcomes.

All of the aforementioned risk factors represent an alarming failure for veterans to successfully reintegrate into civilian life and experience a good quality of life. Of course having any one of these risk factors does not inherently mean a veteran will commit suicide, however, it is obvious that they would be placed at higher risk. Considering the range of negative consequences PTSD has on the veteran population, there is an overwhelming need for additional help. This additional help comes in the form of art therapy.

Art Therapy Sessions and Activities.

A typical session of art therapy includes three segments. In the beginning, time is allotted for participants to "check in," which establishes an emotional starting point for participants.[41] The middle segment generally includes an "artistic prompt" where participants are actively involved in producing artwork. The end segment is intended to "wrap up" by sharing meaningful dialogue regarding the artwork. There are various activities involved in the application of art therapy, several of which are described below. Although art therapy may derive from a variety of activities, it is important to keep in mind that the purpose of healing is not lost, it is simply approached from different avenues.

One of the most popular activities in art therapy is drawing. This activity may be conducted in different ways using different guidelines; however the premise is for participants to draw pictures expressing their inner thoughts and then share dialogue describing their artistic depictions. Another widespread activity found in the use of art therapy is photography. This activity may also be seen taking place in many different ways using different guidelines. Essentially, photo art therapy gives visual form to personal feelings by capturing meaningful precise moments in the activities of participants' daily lives. In addition to these activities used in art therapy there are numerous others available, including: painting, poetry, dance, instrumentals, vocals, songwriting, acting, quilting, crocheting, and sculpting, just to name a few.

Art therapy and PTSD outside of the US

It is important to note that art therapy and PTSD are not unique to the US or this generation of soldier. Art therapy and PTSD have existed for decades in research and practice, with a great deal of work having been pioneered in the UK. Consequently, researchers across the globe are achieving great inroads in examining and innovating the practice of art therapy among military veterans.

Adrian Hill, a British soldier, artist and author, first coined the term "art therapy" in 1942 following his service in World War I as an official war artist on the Western Front.[42] Hill's work emphasised art-making itself as healing, which has greatly influenced the development of various art therapy models, and stands in contrast to Margaret Naumberg's psychodynamic approach, where the central focus of understanding artwork is a result of the relationship between the client and therapist.[43] There are several noteworthy organisations in the UK that support wounded soldiers, two of which are mentioned next.

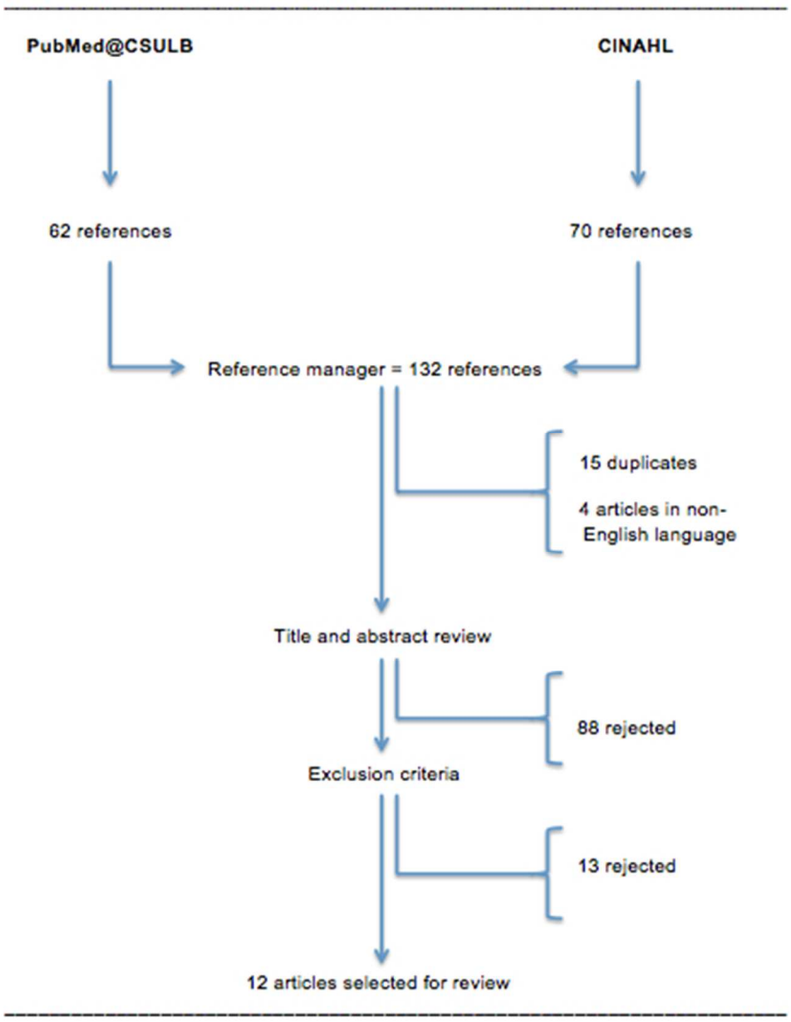
Founded in 1919, Combat Stress is a charitable organisation that works to provide timely, effective clinical treatment and welfare support to veterans who suffer from PTSD.[44] Help for Heroes (H4H), is a military charity founded in 2007.[45] H4H provides individual and family support for wounded soldiers with state-of-the-art recovery centres. Each of these organisations has received national acclaim for their efforts in supporting veterans with PTSD.

Methods

This comprehensive in-depth literature review was guided using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement. An electronic literature search of databases was conducted using CINAHL and an enhanced version of PubMed, named Pubmed@CSULB. Relevant journal articles reflecting the use of art therapy among persons with PTSD were identified from each database. Papers containing the terms "art therapy" and "post traumatic stress disorder" as subject headings were identified and used as inclusion criteria for our review. This broad approach was necessary, given the dearth of existing research covering the use of art therapy among persons with PTSD, especially when applied to the veteran population. No preference was given to studies that emphasised qualitative or quantitative research methodology – both were selected. In addition, papers published in "English only" were selected, and there were no restrictions on publication date or status. The literature search identified 132 references (Figure 1).

There were 14 references found present in both of the database searches, as well as one duplicate reference found in the PubMed database search, which lead to 15 of the 132 references being excluded because of duplication. Also, four references were excluded for being in a non-English language. A total of 113 references then had their titles and abstracts reviewed for relevance, 88 of which were rejected as these studies were unrelated and primarily involved the use of antiretroviral therapy (ART), which is a combination of medications used to suppress the HIV virus and stop the progression of HIV disease. Afterwards, an additional 13 references were rejected which included case studies, reviews, and recommendations showing no data, as well as papers where art therapy was not the central treatment or focus. Only 12 articles met our criteria and were selected for review.

Figure 1. Selection of Articles in the Databases



Results

Although art therapy has been more widely researched among other populations (i.e., abuse and disaster survivor populations), there were several articles found which support art therapy's success in producing positive health outcomes for veterans of military service (Table 1). The majority of these articles suggest that through the practice of art therapy, patients with PTSD experienced at least three significant outcomes: 1) the ability to express thoughts which could not previously be verbalised, 2) improved social relationships which led to reduced social detachment, and 3) a general reduction in re-experiencing, hyper-vigilance and avoidance/ emotional numbing symptom clusters with notable improvements in experiencing less anxiety, being able to control intrusive thoughts, and feeling less emotionally numb. All relevant studies are summarised in Table 1 and listed in order by category, based on type of trauma, including: war veterans; serious medical condition; war/ conflict survivor or refugee; disaster survivor; sexual abuse; mixed types of trauma; and lastly, physical injury.

Table 1. Articles on Art Therapy and Post-Traumatic Stress Disorder

Author(s) & Title	Journal	Type of trauma	Main results
Kopytin, A., & Lebedev, A. (2013). Humor, Self-Attitude, Emotions, and Cognitions in Group Art Therapy With War Veterans.	Art Therapy, 30(1), 20-29.	War veterans	112 war veterans received treatment for PTSD and were randomly assigned between an experimental group (art therapy) and control group. Increased humor and creative problem solving, and self-esteem were found among the experimental group.
Rademaker, A. R., Vermetten, E., & Kleber, R. J. (2009). Multimodal exposure-based group treatment for peacekeepers with PTSD: A preliminary evaluation.	Military Psychology, 21(4), 482-496.	War veterans	A series of multimodal exposure-based group treatments was conducted on a sample of UN peacekeeping veterans diagnosed with PTSD. The exposure-based multimodal group treatment in this study revealed a reduction in PTSD and associated symptoms.
Forzoni, S., Perez, M., Martignetti, A., & Crispino, S. (2010). Art therapy with cancer patients during chemotherapy sessions: An analysis of the patients' perception of helpfulness.	Palliative and Supportive Care, 8(1), 41-48.	Serious medical condition	A study of 54 cancer patients receiving art therapy revealed 1) art therapy was perceived as generally helpful (37.3%), 2) art therapy was perceived as helpful because of the dyadic relationship (33.3%), 3) art therapy was perceived as helpful because of the triadic relationship, patient-image-art therapist (29.4%).
Goodsmith, L. (2007). Beyond where it started: a look at the "Healing Images" experience.	Torture: Quarterly Journal on Rehabilitation of Torture Victims and Prevention of Torture, 17(3), 222-232.	War/conflict survivors and refugees	A group of conflict refugees participated in an eight-week digital photography therapy program. All of the group participants strongly supported expansion of the treatment program.
Baker, B. A. (2006). Art speaks in healing survivors of war: The use of art therapy in treating trauma survivors.	Journal of Aggression, Maltreatment & Trauma, 12(1-2), 183-198.	War/conflict survivors and refugees	Bosnian refugees participated in an art therapy program for a period of five years. This study demonstrated an increase in participants' social interactions, thus reducing isolation.

Chilcote, R. L. (2007). Art therapy with child tsunami survivors in Sri Lanka.	Art Therapy, 24(4), 156-162.	Disaster survivors	A four-week art therapy treatment series was administered to a group of 113 children who had survived the December 2004 tsunami in Sri Lanka. This study found that the Sri Lanka tsunami survivors were able to work through their intrusive thoughts and express their trauma and pain (not previously verbalized) in artwork.
Pifalo, T. (2006). Art therapy with sexually abused children and adolescents: Extended research study.	Art Therapy, 23(4), 181-185.	Sexual abuse	A group of sexually abused children diagnosed with PTSD underwent an eight-week treatment series of art therapy and CBT. This study found a significant reduction in PTSD symptoms among the sexually abused children.
Allen, K. N., & Wozniak, D. F. (2010). The language of healing: Women's voices in healing and recovering from domestic violence.	Social Work in Mental Health, 9(1), 37-55.	Sexual abuse	A statistically significant reduction in PTSD symptoms was noted, including: intrusive/re-experiencing thoughts, avoidance/numbing, and hyper-vigilance.
McMackin, R. A., Leisen, M. B., Sattler, L., Krinsley, K., & Riggs, D. S. (2002). Preliminary development of trauma-focused treatment groups for incarcerated juvenile offenders.	Journal of Aggression, Maltreatment & Trauma, 6(1), 175-199.	Mixed types of trauma	Participants of this study reported increased understanding of their trauma experience and how it influenced their criminal behavior, particularly their use of violence and substance abuse.
Lyshak-Stelzer, F., Singer, P., St. John, P., & Chemtob, C. M. (2007). Art therapy for adolescents with posttraumatic stress disorder symptoms: A pilot study.	Journal of the American Art Therapy Association, 24(4), 163-169.	Mixed types of trauma	In a study conducted in the Greater New York metropolitan area, 29 adolescents were separated into two treatment groups: treatment-as-usual (TAU) group, and the trauma-focused art therapy (TF-ART) group. The TF-ART group experienced a significant reduction in PTSD symptoms.
Schreier, H., Ladakakos, C., Morabito, D., Chapman, L., & Knudson, M. M. (2005). Posttraumatic stress symptoms in children after mild to moderate pediatric trauma: A longitudinal examination of symptom prevalence, correlates, and parent-child symptom reporting.	The Journal of Trauma and Acute Care Surgery, 58(2), 353-363.	Physical injury	Children with PTSD as a result of physical injury underwent a single-session of art therapy. After a follow-up period of 1, 6, and 18 months, results showed no sustained effects on the reduction of PTSD symptoms.

Chapman, L., Morabito, D., Ladakakos, C., Schreier, H., & Knudson, M. M. (2001). The effectiveness of art therapy interventions in reducing post traumatic stress disorder (PTSD) symptoms in pediatric trauma preliminary evaluation.	Art Therapy, 18(2), 100-104.	Physical injury	A study of children with PTSD receiving the Chapman Art Therapy Treatment Intervention (CATTI) found no difference in reduction of PTSD symptoms between the experimental and control groups. However, a reduction in acute stress symptoms was noted.

Discussion

The overwhelming majority of studies included in this review suggest that patients receiving art therapy as treatment for PTSD experienced positive health outcomes. It is important to point out that the only studies with no significant differences were also the only studies of the review that were 1) physical injury trauma types, and 2) used a one-time only art therapy session, rather than multiple sessions, as the other studies had. Each study is discussed next.

War veterans. The first two studies listed in Table 1 specifically include war veterans as their sample population. Kopytin and Lebedev conducted a study on 112 male and female war veterans being treated for PTSD.[46] These veterans were randomly assigned between a control group and an experimental group, which lasted 12 – 14 sessions. Results showed that the experimental group experienced increased humour and creative problem solving as well as improved self-esteem.

Rademaker et al. conducted the next study on war veterans. Rademaker et al. retrospectively collected data from 22 male veterans with PTSD, who had served as UN peacekeepers from August 2003 to March 2006.[47] A series of multimodal exposure-based group treatments, which included creative arts therapy, was conducted. While using exposure-based multimodal group treatment this study revealed a reduction in PTSD symptoms among veterans.

Serious medical condition. Forzoni et al.[48] conducted a study of 54 patients diagnosed with PTSD and a serious medical condition (cancer) to find out if patients with PTSD perceived art therapy as helpful and in which way art therapy was perceived helpful. Their findings revealed: 1) art therapy was perceived as generally helpful, 2) art therapy was perceived as helpful because of the dyadic relationship, and 3) art therapy was perceived as helpful because of the triadic relationship, patient-image-art therapist.

War/ conflict survivors and refugees. Two of the studies addressed art therapy use among war/ conflict survivors and refugees with PTSD. Goodsmith published a paper on conflict refugees participating in an eight-week digital photography therapy program called "Healing Images."[49] These refugees had suffered different types of torture (i.e., burns, rape, and forced positions). After their participation in the digital photography program, all of the group participants strongly recommended expansion of the program. In addition, there was overwhelming agreement that their experience was caring and allowed for self-discovery.

Baker conducted a separate study on Bosnian refugees participating in an art therapy program, which lasted over a period of five years 50. All subjects were separated into male and female groups and were above the age of 55. While the male group completed artwork such as: drawing, painting, and sculpting, the female group used embroidery, needlepoint, crochet, knitting, needle-lace, and quilting. Each art project was followed up with discussion. The results of this study demonstrated an increase in participants' social interactions, thus reducing avoidance symptoms.

Disaster survivor. Chilcote conducted a four-week art therapy treatment series to a group of 113 female children, ages 5 to 13, who had survived the December 2004 tsunami in Sri Lanka 51. All subjects had experienced either the loss of a loved one, damage or loss of home, and/ or witnessed the tsunami. The art activities in the treatment series included using basic supplies of white copy paper, pencils, watercolor paint sets, and washable markers to produce drawings and paintings related to their traumatic experiences. This study found that the Sri Lanka tsunami survivors were able to work through their intrusive thoughts and express their trauma and pain, which they had not previously been able to verbalise.

Sexual abuse. Pifalo conducted a study on a group

of sexually abused children, ages 8 to 16, who were diagnosed with PTSD.[52] Subjects of this study underwent an eight-week treatment series consisting of art therapy and CBT. While analysing results from the pre- and post-test treatment Trauma Symptom Checklist for Children, this study found a significant reduction in PTSD symptoms, including: anxiety, depression, anger, posttraumatic stress, dissociation, dissociation-overt, sexual concerns, sexual preoccupation, and sexual distress.

Allen and Wozniak conducted a study on a group of 11 women recruited through domestic violence agencies.[53] Using the PTSD checklist, a statistically significant reduction in PTSD symptoms was noted in 8 of the 17 items, including: repeated, disturbing memories or thought; reliving stressful experience; avoid thoughts/ feelings related to stressful experience; feeling emotionally numb; feeling as if the future will be cut short; trouble sleeping; and, feeling easily startled.

Mixed traumas. Two studies focused on art therapy among patients with different traumas leading to PTSD. McMackin et al. examined incarcerated juvenile offenders with PTSD participating in a group therapy program.[54] The types of trauma varied among the sample population (i.e., physical and or sexual abuse, witnessing severe injury, etc.). The program lasted from 10-12 weeks and each session included either an art activity or discussion. Following the program, participants reported increased understanding of their trauma experience and how it influenced their criminal behavior, particularly their use of violence and substance abuse.

In the second study, Lyshak-Stelzer et al. examined the efficacy of trauma-focussed art therapy among adolescents with PTSD.[55] Twenty-nine adolescents in the Greater New York metropolitan area were separated into two treatment groups: treatment-as-usual (TAU) group, and the trauma-focused art therapy (TF-ART) group. The TF-ART group met for 16 sessions and each participant completed at least 13 drawings. The TAU group also met for 16 sessions, however discussion was the focus for 14 of the sessions and arts and crafts were included in two of the sessions. Although both treatment groups exhibited improvement, the TF-ART group experienced a significant reduction in PTSD symptoms.

Physical injury. Only two of the 12 studies reviewed showed no significant difference in reducing PTSD symptom severity. The first study conducted by Schreier et al. examined children with PTSD as a result of physical injury, all of whom underwent a single-session of art therapy.[56] After a follow-up period of 1, 6 and 18 months, results showed no sustained effects on the reduction of PTSD symptoms.

The second study was a prospective, randomised cohort design conducted by Chapman et al.[57] This study included 85 children, ages 7 to 17, who were admitted to a Level 1 Trauma centre for injuries. In addition to receiving medical care for sustained injuries, subjects were assigned to a control group and an experimental group. The experimental group participated in the Chapman Art Therapy Treatment Intervention (CATTI). This study found no difference in reduction of PTSD symptoms between the experimental and control groups, however it is important to note that a reduction in acute stress symptoms was found.

Limitations

Although the aims of this study had been reached, there were several limitations. First, this study was primarily limited by its small sample size. To more accurately generalise the results of this study, the sample size could have been expanded to include more than two electronic databases for searching articles. An earlier start in data collection would have increased the amount of time needed to search through additional electronic databases. Second, as further research on PTSD has been taking place, the classification and criteria used to diagnose PTSD have recently changed, which may influence the findings of this study and other similar studies. Since it was first introduced into the DSM-3 in 1980, PTSD has been classified as an anxiety disorder, however in the DSM-5 released in May of 2013, PTSD has been reclassified as a trauma and stressor-related disorder. Moreover, in what have traditionally been known as the triad symptom clusters: re-experiencing, avoidance/ emotional numbing, and hyper-vigilance, the DSM-5 splits the clusters, adding a fourth named negative cognitions and mood.[58] Also, it is important to note that sexual assault is newly included in the DSM-5 as diagnostic criteria for PTSD. Third, it is unavoidable that in this study, a certain degree of subjectivity can be found. An increased number of experienced researchers commissioned to independently and systematically review the studies would have offered more objectivity, and thus have benefited the results of this study.

Conclusion

Challenges of military service should be met with a supportive culture that is open to implementing art therapy as a treatment modality in addition to current evidence-based practices. This review suggests that if current service members and veterans were placed

into art therapy programs as early as possible after being diagnosed with PTSD, they would be at less risk for developing greater PTSD symptom severity. The preferred method of treatment for patients with PTSD receiving care in the VA healthcare system is CBT, however, since CBT is effective in treating only two of the three symptom clusters, it is an incomplete care package. Given the effectiveness art therapy has in treating the third symptom cluster, it is not meant to replace CBT, but rather it is meant to be offered in addition to CBT in order to produce a more comprehensive care package for past and present service members with PTSD.

Corresponding author: Jeremy Ramirez, BS, MPH-C
Authors: J Ramirez[1], E Erlyana[2], M Guilliaum[2]
Author Affiliations:
[1] University of California, Berkeley
[2] California State University, Long Beach

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The Legacy of the Anaesthesia 'Events' at Pearl Harbor, 7th December 1941.

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Dr John A. Crowhurst

Dr John A. Crowhurst, Emeritus Consultant Anaesthetist Women's & Children's Hospital, North Adelaide, SA 5006. Postal address: PO Box 6090, Linden Park, SA 5065 Australia. [e-mail: jacrow@optusnet.com.au]

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'For the past 73 years, since the Japanese military attack on the US naval base at Pearl Harbor on 7th December, 1941, most anaesthetists have been taught that the sodium thiopentone (Pentothal®) anaesthesia caused hundreds of perioperative deaths in the 1178 casualties of the battle'.[1] It is believed that about 1,000 of these required emergency surgery in the subsequent 24 - 48 hours.

When I was a medical student attached to the Anaesthesia Department at the Royal Adelaide Hospital in 1971, my consultant said to me:

> "Lad, if you go on to do Anaesthesia, you must use this thiopentone with great care and diligence because the Yanks killed more of their own at Pearl Harbor than did the Japanese in their attack in 1941."

When I asked how did he know this, he replied that he was told that when he was a trainee in Belfast in 1949! That story has been told to thousands of anaesthesia trainees all over the world, including the USA, and is succinctly reviewed by Prof. Selma Calmes in the video presentation 'Pentothal and Pearl Harbor' on-line at the Wood Library-Museum website.[2]

In 1992, the year after the 50th anniversary of the attack, Dr Frank Bennetts, a consultant anaesthetist in Kent, and an active member of the History of Anaesthesia Society, published in the U.S. Anesthesia History Association's Newsletter a review of thiopentone anaesthesia since its introduction into specialist practice in 1934, entitled: 'Thiopentone, Chicago to Pearl Harbor'[3], which included much detail about its use at Pearl Harbor.

'Then, in 1995, after reviewing US military documents released under the US Freedom of Information Act (1946), he published what has become the most definitive paper on the Pearl Harbor anaesthesia events.[4] That paper acknowledged that censorship by the US military of the extent of thiopentone morbidity/mortality was possible, because no actual numbers of such complications have been revealed by the military authorities, notwithstanding that few detailed records of anaesthesia were kept. The only official figures cited were from one civilian-military hospital, the Tripler Army Hospital, which is about five miles from Pearl and which employed some civilian surgeons whose anecdotes and accounts were not subject to strict military policy.'[1]

Bennetts concluded: *"...it is clear that the rumoured death rate from this cause has been greatly exaggerated."* I suspect that the death rate which Dr Bennetts was referring to, was the anecdotal one

alluded to me in 1971, and which was also told to him as cited in his 1992 paper.[3]

I disagree with his conclusion that the *rumoured* death rate was greatly exaggerated, but accept the fact that the actual number of true anaesthetic deaths will never be known because few, if any, detailed records were kept, and because there was no clearly defined classification of anaesthetic deaths, as there is today. Many such World War II (WW2) fatalities were classified as 'having died of their wounds', or 'during surgery'.[5]

In 1941, the hazards of using thiopentone in severely shocked patients were unknown to the military nurse anesthetists and others who were responsible for administering anaesthesia at Pearl Harbor. 'Cardiovascular collapse and respiratory arrest together with a shortage of oxygen supplies, lack of resuscitative skills and equipment and knowledge of thiopentone's pharmacology and dosage, along with a dearth – possibly none – of trained, skilled, physician anaesthetists clearly resulted in several tragedies'.[1] But just exactly how many will never be known. 'Some spinal anaesthetics too contributed to the peri-operative mortality, and the available local anaesthetics, procaine and tetracaine, were quickly restricted to infiltration only – mainly in burns patients'.[1]

A year after Pearl Harbor, Admiral Gordon Taylor RN, said: *"Spinal anesthesia is the ideal form of euthanasia in war surgery"*; and Dr MJ Halford, a senior surgeon at Pearl Harbor, added: *"...and let it be said that intravenous anesthesia is (also) an ideal method of euthanasia."*[5] That paper in Anesthesiology in January 1943 prompted a four page Editorial entitled: 'The question of intravenous anesthesia in war surgery'.[6] The 'question' discussed the overall safety of thiopentone and outlined in great detail the extreme dangers it heralded in shocked patients, and under conditions of war. The 'warnings' were based on '...partial reports of military experience...' and not on '...thorough trial under both laboratory and clinical conditions in civil circumstances...' Moreover, it is cited that the 'question' required discussion and an answer because '... it had occupied the minds of physicians and surgeons since the attack on Pearl Harbor, and partly as a result of the happenings there.' Other papers in that and in many other 1940s issues of *Anesthesiology* and in many other journals during 1942-43 carried similar messages. But nowhere are those 'happenings' quantified.

It is not surprising therefore that during (and after) that *infamous* day in 1941 the nurse anesthetists, surgeons and others responsible for anaesthesia quickly reverted to using and requesting 'drip ether' as the preferred anaesthetic technique. A review of endotracheal anaesthesia techniques used in the US military in 1945 in Italy cited only 10% included thiopentone.7 Indeed, even in 1950, in the Korean war, the US Military's nurse anesthetists continued to use 'drip-ether', as depicted in some 5 episodes of the TV series M*A*S*H.[8] In that war too, US anaesthesia equipment was not standardised and could not be shared with the British and other allied medical teams.9 That is not to say that thiopentone was not used in small intermittent doses, but its use in full induction-doses was unlikely because after Pearl Harbor, the hazards of its use in shocked patients were quickly appreciated by physician anaesthetists, who began to use smaller, intermittent doses.[6,7,10] Moreover, after Pearl Harbor, the Mayo Clinic's use of thiopentone declined markedly, whereas the drug's popularity continued to increase in UK hospitals and throughout the world as more physicians took up anaesthesia as part of their medical practice. (See Table 1.)

Table 1. Prevalence of thiopentone usage 1941-1951. From Dundee JW (Ed). Thiopentone and other thiobarbiturates. Edinburgh: E.S Livingstone, 1956;10-12.

	Mayo Clinic	UK Hospitals
End 1941	30%	9.5%
End WW2	24%	25%
End 1951	52%	76%

This decline at the Mayo Clinic is very significant because it was in the early 1930s that the US anesthesiologists Prof. Ralph Waters in Wisconsin and Dr John Lundy at the Mayo Clinic in Rochester US who initially researched thiopentone and introduced it into clinical practice.[12] They demonstrated clearly thiopentone's many advantages over ether and other thiobarbiturates.[11,12,13]

Ironically, Prof. John Dundee, in his 1956 *'Thiopentone and other Thiobarbiturates'* textbook and in his other 37 publications on thiopentone, did not comment on this marked decline in its use at the Mayo clinic, whilst the drug's popularity soared elsewhere, especially in Britain where all anaesthesia was administered by doctors.[11,14]

In 1942, the US National Research Council established an Anesthesia Committee to oversee physician training and to improve anaesthesia in the European Theatre of Operations. This committee, which was chaired by Prof. Ralph Waters also included Prof. Henry Beecher, Drs John Lundy and Ralph Tovell had far-reaching powers to recruit and train doctors as anesthetists for the US Military.[10,13]

By 1943, this committee had begun to address the lack of 'trained anesthetists' and scarcity of

appropriate equipment such as portable, closed respiratory/ventilation systems which were major contributors to anaesthetic mortality and morbidity.[3,7,14,19] The committee dragooned many young US doctors into three-month training courses, some of which were conducted in Britain for Allied Forces under the auspices of Prof. Macintosh and other British colleagues.[10]

It is important to appreciate that in 1941 Anesthesiology was not recognised as a medical discipline in the Surgeon General's Office in the US military, and had minimal medical status throughout the US until after Pearl Harbor and WW2.[15,16,17] Rather, nurse anesthetists were employed almost exclusively at Pearl Harbor, although some doctors with some anaesthesia experience were involved. Official training of nurse anesthetists began only after the foundation of the National Association of Nurse Anesthetists in 1931 and was only really standardised and recognised in the late 1940s.[18,19]

The American Board of Anesthesiology was constituted in 1939 and, by the end of 1941, there were only about 100 certified, physician anesthetists in the whole of the US, with less than 50 in the military, whereas in England, the Diploma of Anaesthetics of the Royal Colleges of Surgeons and Physicians had begun in 1934, and anaesthesia was practised only by doctors.a Undoubtedly, these significant differences between the US and Britain, and other countries, in the status, recruitment and training of personnel responsible for anaesthesia services contributed to the 'anaesthesia events' at Pearl Harbor.[a]

In the US, back in 1937, Prof. Ralph Waters, who was one of the principal educators of nurse anesthetists, had attempted to convince surgeons of this long before Pearl Harbor, when he wrote:

> *"Anesthesia received little aid or stimulation by surgeons who frowned upon medical men to improve the status of anesthesia. This attitude placed anesthesia into the hands of young assistants and nurses or technicians."*[16]

Halford, in his classic paper in *Anesthesiology* (1943), just a year after Pearl Harbor, stated that the army needed 'anesthetists' and appealed to any 'trained/qualified men' to apply for a commission and join surgical teams.[5] That appeal, in *Anesthesiology* was clearly directed at doctors – not nurses.

Today, in the US, specialist physician anaesthetists are referred to as 'anesthesiologists', whilst nurses and others who are not specialists are 'anesthetists'. (The term 'anesthesiologist' denoting a physician anaesthetist, came into common use only in the 1940s, when more doctors adopted Anaesthesiology as a career;[17,20,21] whereas, in most of the rest of the world, physicians had always been the principal practitioners of anaesthesia.) During and after the War many doctors concurred with Halford's plea and within a few years appropriate anaesthetic training courses were established, and in due course, many of those so trained gained specialist/consultant recognition and status.[13,22,23,24]

'These WW2 tragedies, especially those at Pearl Harbor, were a wake-up call for surgeons and the medical profession generally throughout the world to improve Anaesthesia. Finally, in the US, it had become clear that no longer was it appropriate for any junior doctor, nurse or technician to administer 'sophisticated' anaesthesia for many surgeries, and especially to critically-ill patients.'[1] This had been known for many years in thoracic and neurosurgery, at specialist clinics such as the Mayo, and in many other countries.[16,21,22,23] Nevertheless, today some 17 nations have large contingents of nurse anesthetists, who, in some regions still practise independently.

As the WW2 progressed, portable, closed-system breathing circuits enabling the safe administration of ether with either oxygen ± air ± nitrous oxide ± ether using spontaneous or assisted ventilation became more widely available. The types of apparatus used are well illustrated in the WW2 review documents published by the US Army Medical Department.[24]

Through the 1940s and after WW2, it was quickly recognised that the profession required appropriately trained anaesthetists with the knowledge and skills to use such drugs as thiopentone and the sophisticated equipment developed, especially by the British. The Royal Colleges of Surgeons established Faculties of Anaesthetists, and universities in Australia soon introduced post-graduate medical diplomas in Anaesthesia, following the example of the 1934 D.A. in England.

Specialist recognition was enhanced throughout the developed world, in the British Empire and especially in Britain by the establishment of the National Health Service in 1948. Until then most practising anaesthetists were general practitioners, many of whom had gained a post-graduate diploma – the D.A. But by the mid 1950s, once Anaesthesia had been recognised as a medical speciality, education, research and development progressed rapidly, and examinations for Fellowship of the Faculties, not just Membership, began in1953 as outlined in Table 2.

[a] Smith Bradley E. Personal Communication. March 2014

Table 2 'Significant Developments in Anaesthesiology after Pearl Harbor.'*

Education and Specialist recognition:

1946 Journal: Anaesthesia (the eighth Anaesthesia journal)

1947 Diploma of Anaesthetics Course, University of Sydney

1948 Faculty of Anaesthetists, Royal College of Surgeons, England.

(170 Fellows elected – some from Australia)

Diploma Courses, FARCS England and the University of Melbourne.

National Health Service, Britain.

1952 Faculty of Anaesthetists Royal Australasian College of Surgeons

1953 Faculty of Anaesthetists Royal College of Surgeons, Ireland Fellowship of FARCS Examination.

Drugs, Equipment and Techniques:

1941 Trilene®; Caudal epidurals

1942 Curare (purified d-Tubocurarine); Carlen's Tube

1943 Macintosh laryngoscope

1945 Tuohy needle and first use of 'ureteric' epidural catheters

1947 'Balanced' anaesthesia with Pethidine

1948 Lignocaine; Methadone; 'Copper Kettle' Vapouriser

1949 Scoline®; Apgar Score

1950 Hypothermia (Cardiac & Neurosurgery advances)

1952 IPPV with bag ventilators & ETT

1954 Mapleson breathing systems; Halothane

* Adapted from Table 1.1

Following the British model, university and teaching hospitals in Australasia began to establish teaching departments of anaesthesia in the 1950s, whose roles included resuscitation and critical care, soon to be known as Intensive

Care, which, along with Emergency and Pain Medicine subsequently became specialities in their own right. These specialities began as Faculties within Anaesthesia, just as Anaesthesia itself had begun as a Faculty within Surgery.'[1]

Having reviewed more than 100 publications by surgeons and others in the years following WW2, and visiting and corresponding with many colleagues and others in the US, I am convinced that the thiopentone mortality rate was considerably higher at Pearl Harbor than the 'official' WW2 rate of 1:450 cited in a review of casualties published by Beecher in 1955.[19] That rate included similar anaesthetic mortalities from many other theatres of the war, including Italy and North Africa, and, arguably, was one of the first attempts to accurately define and classify anaesthetic mortality.[19,20]

During a visit to Pearl Harbor and the USS Arizona Memorial in November 2014, I met with two of the nine surviving US Navy veterans, neither of whom could tell me anything about any anaesthesia 'events', except that one of them, when I asked if he had had 'the ether' when he had shrapnel removed from his head, said: "No. I had an injection." Then he pointed to his right cubital fossa. He said all went well with the surgery, but the next day the surgeon told him he had 'died' during the operation, but that they had resuscitated him. Thus he had received an intravenous anaesthetic, almost certainly thiopentone, but had suffered no sequelae.

'In summary, the significance and legacy of the anaesthetic events at Pearl Harbor were that surgeons, the medical profession generally, and health authorities, recognised the need for appropriately trained and skilled, specialist practitioners of anaesthesia. Today's modern speciality of Anaesthesia, or Anaesthesiology, as I suggest we should refer to it, was born soon after Pearl Harbor and WW2, and the 'Ether Century' began to expire, although ether did continue to be used into the 1970s for many simpler surgeries in less developed centres, principally by GP anaesthetists.'[1]

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Note: Many other references, communications and sources of accounts of events at Pearl Harbor reviewed for this presentation, but not cited, are available on request to the author.

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THE "TRIANGLE OF DEATH" Medical Sustainability in Expeditionary Sea-Based Operations

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Captain Arthur M. Smith,Medical Corps, U.S. Navy Reserve (Retired)

Captain Smith, a frequent contributor to the Naval War College Review, is adjunct professor in both the Department of Surgery and the Department of Military and Emergency Medicine at the Uniformed Services University of the Health Sciences in Bethesda, Maryland. He is also professor of surgery (urology) at the Medical College of Georgia, in Augusta.

The futuristic concept of joint, geographically dispersed, expeditionary (or "distributed") operations emanating from bases at sea entails many challenges. Among them are the formulation and design of afloat casualty-care capabilities, especially where maneuver forces are inserted into territories devoid of land-based logistic support. In expeditionary amphibious operations during the past century, ad hoc creative shipboard adaptations for treatment and salvage of the combat wounded occasionally proved successful and functionally effective. If flexible and adaptive joint operational medical support is to be made available in the future, an appreciation of these historical achievements is essential. Further, if the frequently irretrievable physical deterioration of the injured—metaphorically, the "triangle of death"—is to be avoided, familiarity with the immediate needs of the combat wounded is likewise imperative, especially the unique requirements of wounds seen in contemporary armed conflict.

The Operational Context: Distributed Sea-Based Operations

Sea-based forces in the future will be involved in a wide array of missions, ranging in scale from disaster relief and humanitarian operations to full-fledged sustained combat at sea and ashore; in some conflicts, the bulk of fighting will be undertaken by joint or combined task forces. In this setting, an inclusive concept of joint sea basing—a "distributed warfighting architecture," attuned to the strategic environment and the likely security challenges of the twenty-first century—has been proposed. A distributed network implies a transformation of maritime forces—fewer maritime platforms, geographically dispersed and integrated with organic and distributed sensor and communications nodes. It connects all the platforms and major systems deployed by the U.S. sea services—ships, submarines, aircraft, unmanned vehicles, and Marine units, as well as joint and combined forces—in a way that facilitates information sharing and affords operational commanders fully networked battle forces.

It is generally postulated that the distributed, sea-based, and networked force will be capable of countering anti-access and irregular-warfare challenges in the littorals and will be less inherently vulnerable. Consequently, it will require less force protection, and will be at less risk of catastrophic mission degradation than traditionally organized forces.[1] Nevertheless, it cannot be ignored that the availability to potential adversaries worldwide of inexpensive, advanced weapons and sensors has increased the risks always associated with ship-to-shore movement. Ample respect must be given to the 250-nautical-mile range of contemporary antiship cruise missiles, as well as to the shallow- and deep-water capabilities of mines (some now incorporating state-of-the-art sensors and processors to complicate countermeasures). Furthermore, these sensors and weapons—which utilize precision, speed, stealth, maneuverability, background clutter, and surprise—will presumably target the afloat sustainment base, whose big, slow ships include prepositioned units with hulls not built to combat standards, these generally characterized as "access sensitive vessels."[2]

Reprinted from: Smith AM. The" triangle of death": medical sustainability in expeditionary sea-based operations. Naval War College Review 2008 Apr 1;61(2):96.

Such ships invariably have little time to defend themselves against weapons employed at the short ranges likely in the littoral. This was exemplified by the sinking of the unarmed but strategically important British transport MV Atlantic Conveyor by an errant Argentine Exocet missile while it carried multiple helicopters to support United Kingdom forces in the Falkland Islands.[3]

In addition, the complicated task of preventing or rapidly detecting the laying of mines, and the subsequent difficulty or impossibility of clearing them in waters covered by a coastal defense system (including diesel submarines and missile-equipped fast patrol boats) will ultimately oblige task force ships with their medical facilities to move to seaward. That, in turn, will have major implications for casualty survival.

Avoiding The Triangle Of Death

The expeditionary logistical calculus must always include the possibility of human casualties (sickness or wounds, incurred ashore or at sea), and that reality must be factored into every operational equation. Contingency health care considerations must be integrated into plans; neglect of these critical elements can ruin any grand operational design.

Unfortunately, forward medical support in an over-the-horizon insertion of forces into hostile terrain, far from supporting facilities and with no initial lodgment ashore, can be hampered by isolation and dispersal of units, obstacles to tactical radio communication, and limits on vehicular transportation. Small units will be required to extract and evacuate their own casualties, with resultant delays in meaningful treatment.

Concurrently, as a result of the current mandate for compactness and simplicity of maneuver units, landing force medical units have been lightened and downsized. Though combat operations could penetrate some two hundred miles inland, the technical capabilities of their medical assets have been lessened. All this implies greater dependence upon afloat resources, with the hopeful, but perhaps unrealistic, expectation that the sick and wounded can be rapidly evacuated to them. Unfortunately, sea-based operations may be subject to geographic limitations, making the time and distance constraints upon timely delivery of casualty care formidable. Although bases established at sea may have access to the approximately 70 percent of the earth's surface that is ocean, ground forces employed or sustained by them only have access to land areas within range of their ship-to-shore aircraft. While various sea-basing scenarios have been structured to support operations with flight distances ranging from 110 to 220 nautical miles from the launching ships, actual inland reach for sea-based aircraft might be considerably shorter for a number of reasons: the ships in a sea base would be expected to remain "over the horizon" at least twenty-five nautical miles offshore to make them more difficult to detect and attack; sea-based ships cannot always be positioned perpendicularly offshore (for the shortest distance) from supported ground units; once over land, aircraft are likely to fly evasive flight paths to make it more difficult for an adversary to position defenses along their routes.

If efforts must be made to avoid air defenses, increases of roughly 30 percent in flight distances can be expected as well. Those considerations could reduce the effective operational reach inland to as little as sixty nautical miles for current aircraft, and about 130 for the planned longer-range heavy-lift rotorcraft. Furthermore, high terrain in the vicinity of the coast could further limit operations because the performance of rotorcraft decreases with increasing altitude. (Many parts of Iran, for example, are mountainous. Nearly 40 percent of Iran's land area and almost half its population are located at elevations greater than five thousand feet above sea level—and would thus present limitations to flight operations, and consequently to casualty retrieval.)[4]

Clearly, retrograde evacuation to ships located far over the horizon may be a delicate and precarious undertaking, not only in its execution but in its impact upon casualty survival as well. The future littoral tactical environment, one of unparalleled complexity, may impede timely evacuation and medical management of casualties; an adversary may logically recognize sustainment as the force's Achilles' heel. Lengthy over-water evacuation may be easily thrown into confusion by sea and weather conditions as well.[5]

The sick and wounded are perishable cargo; whether they survive or die is fundamentally affected by the speed with which they are given medical care. The timeliness of both initial treatment and the evacuation of casualties is extremely important. Even those with potentially salvageable wounds may die or, if they survive, may experience serious complicated disabilities if treatment is not correctly timed. Early first aid, prompt resuscitation of vital functions, and initial stabilizing surgery are particularly important in this process. In essence, delay in treatment due to evacuation lag is tantamount to denial of care to those who could have survived, some without disability with early surgery.[6] In addition, delayed application of treatment to initially simple wounds can facilitate their conversion into complex, infected,

and often life-threatening problems.

For all these reasons, delay in surgical intervention places the wounded in what military trauma circles characterize as the "triangle of death," where they become trapped by the triphasic onset of diminished body temperature (hypothermia), the accumulation of body products of metabolism (acidosis), and the potential for accelerated bleeding (coagulopathy).

An equally important issue is the possibility that large numbers of casualties will accumulate within the sea-based echelon, perhaps very rapidly. During the Falklands campaign in 1982, forty-six deaths and 150 surviving wounded casualties were created instantly by the bombing of the amphibious ship HMS Galahad by the Argentine air force. Most of the casualties were severe burn cases; fire has always been a prominent phenomenon following ordnance explosion within ships at sea.[7]

These occurrences bespeak the danger on both sides of a conflicted coastline.

Consequently, analysis must envision how casualties are generated in littoral warfare, in a continuum of operational realities both on the ground and at sea. Military planners unfamiliar with those realities often suggest that medical evacuation is but an exercise in logistics, in which the number of anticipated casualties, the capacity of transport, the time availability of shuttles, and number of beds available are the primary considerations. This view, which in effect ignores the unique time and resource requirements of wound care, accepts an overall increase in deaths, or at least disability, and the return of fewer personnel to duty. Any new concepts of casualty care must be modulated by the fact that the disturbed, tenuous physiology of the combat wounded cannot be dealt with by standard logistic formulas that equate the movement of stretcher-borne patients with that of ration boxes.[8]

Medical Care at Sea

The history of successful expeditionary medical support demonstrates above all the importance of adaptability and creativity in afloat casualty care. However, the beginnings of sea-based medical support were not auspicious.

Starting from Base Zero: Nelson's Blood

During the eighteenth century, medical care aboard warships was universally poor.[9] The British navy, because of its low social status, poor living conditions, and long stays at sea, attracted only the lowest-quality surgeons, mates, and physicians. On most vessels, surgery and medical treatment were performed in "the cockpit," a small, low, crowded, poorly ventilated, dimly lit room, far below deck. Surgery often involved amputation. The patient was given rum, some other liquor, or opium, if available, and a piece of leather to chew on while the cutting was accomplished. The mortality rate was profoundly high.

But there was no system for evacuating the wounded from battle stations to surgery in the first place. Sailors dragged themselves to the cockpit or were helped by comrades (for which they could be flogged for deserting their stations). Neither was there any system of triage. The wounded presented in line for medical attention; the small complement of medical personnel enforced no priority. Thus, a slightly wounded sailor might be treated while more severely wounded succumbed to shock and bleeding. It was customary to leave patients to recover in hammocks in small areas separated, sometimes, by canvas partitions; these primitive sick bays were located out of the way, in the darkest, least used, and worst ventilated spaces of the ship.

When ground forces were transported, overcrowding increased and losses to disease aboard ships were often higher than normal. To deal with the problem, the Royal Navy provided "hospital ships" to carry the sick, but these vessels generally had no medical personnel aboard, and other ships' physicians were forbidden to leave their own vessels to help. These "hospital ships" became little more than stinking, disease-ridden, floating warehouses where the ill were kept until they either recovered or died.

The French and Spanish navies attempted to return their dead to home port, but in the British navy they went overboard; in fact, a wounded British sailor unable to make his way to surgery was likely to be thrown overboard while still alive. A physician accompanying Lord Cathcart's campaign in the West Indies in 1739 described the conditions on board: "The men were pent up between the decks in small vessels where they had not room to sit upright; they wallowed in filth; myriads of maggots were hatched in the putrefaction of their sores, which had no other dressings than that of being washed in their own allowance of brandy." The ships described were anchored in the harbor of Cartagena (in present-day Colombia); the dead were thrown overboard, where they floated while sharks and birds of prey fed on them in full view of the surviving patients. The latter practice was operative when the legendary Vice Admiral Horatio Nelson, commanding the British fleet at the battle of Trafalgar in 1805, was struck by a bullet that entered his shoulder, pierced his lung, and came to rest at the base of his spine. He retained consciousness for four hours, during

which he reportedly begged the flagship's captain, Thomas Masterman Hardy, not to have him thrown overboard. Captain Hardy agreed, and when Nelson succumbed to his wounds his body was sealed in a cask of brandy for transport back to his father's parsonage.[10]

World War II: The LST(H) and the 7th Amphibious Force

Clearly, medical care at sea has evolved since the eighteenth and early nineteenth centuries. Vice Admiral Daniel Barbey, commander of the 7th Amphibious Force in the Pacific theater during World War II, later noted of his ship's innovative medical capabilities:

> Even before battle casualties started coming in, the staffs of the amphibious ships in Milne Bay [New Guinea] were unequal to the task of caring for those stricken with tropical diseases. There was doubt that a hospital ship would be assigned to the Seventh Amphibious Force… but as a partial substitute we thought we might be able to convert an LST [tank landing ship] into a "first aid" ship if we could spare one and if the Navy Department had no objections… Anyhow, an official request was sent to Washington outlining our reasons and needs. Then, to "save time" we went ahead with the LST conversion plan on the assumption that it would be approved… The LST 464 was chosen because she would arrive in Sydney within a few days where the shipyards could do the work. Two days after her arrival the conversion job was under way and her character changed from a fighting ship to a ship of mercy… Assembling equipment in the States would not have been a matter of consequence, but getting it in war short Australia required a lot of priorities. The ship's medical staff… were obtained by "thinning out" other ships and shore bases.[11]

LST 464 subsequently became the main reliance for medical service in the 7th Amphibious Force. In early operations it was stationed at advanced bases to receive casualties from other amphibious craft for transport to Milne Bay. As other ships joined the force and operations became larger, additional units were converted into "casualty ships." Surgical teams were embarked for the emergency handling of the wounded evacuated to these medically outfitted ships, designated as LST(H)s. These special LSTs, which like normal units carried combat troops and equipment to the assault, could remain "beached" for surgery after disembarking them. Planners saw the value of using LST(H)s this way in the Philippine Archipelago in 1944 at the battle of Leyte Gulf, and also of holding one or two in reserve, to be committed to beaches overwhelmed with casualties or without medical facilities. As recalled by Admiral Barbey, "Since Army hospitals ashore could not be set up as rapidly as anticipated because of heavy rains, LST 464 remained in the harbor and became the most important medical facility afloat or ashore for several days."[12]

Admiral Barbey concluded, "Our first aid ship did a magnificent job throughout the war. Ironically, nine months after her conversion, and after she had handled some thousands of sick and wounded, a letter was received from the Bureau of Ships regretfully turning down our conversion request: 'It is desired that all LSTs continue to operate in the manner for which they were designed.' The letter was placed in those files most likely to be lost in combat, and the LST 464 continued to operate, if not in the manner for which designed, at least in the way we most needed her."[13]

Casualties being brought aboard a beached LST (U.S. Navy Bureau of Medicine and Surgery Historian)

An LST tank deck with casualties (U.S. Navy Bureau of Medicine and Surgery Archives, BUAER 435557)

The Evolution of Hospital Ships

During the operation at Lingayen Gulf in 1945, six LST(H)s were beached to provide surgical care. At Normandy in 1944, all LSTs were equipped to handle returning casualties, and fifty-four were outfitted to perform surgery. Others were subsequently equipped to serve as casualty control ships, regulating the retrograde flow of the wounded to rear facilities. One was even made into a floating blood bank. Such hospital LSTs, able to provide surgical care in a relatively safe environment close to shore, performed even under fire at Iwo Jima and Okinawa.

World War II

Another scenario-driven innovation of World War II that contributed to the evolution of modern hospital ships was a group of three APHs, converted personnel transports with medical modifications. The attack personnel transport (APA), although not designed or equipped to handle casualties, often bore the brunt of initial casualty transfers from beach assaults—for example, at Iwo Jima. An APH (which could carry landing forces inbound) was considered preferable, because it had a complete staff of medical specialists and a large sick bay, so specialized treatment could be administered. Operating outside Geneva Convention protections, the camouflaged and heavily armed APH carried eight to twelve medical officers and sixty hospital corpsmen (no nurses were assigned). Each ship was capable of transporting 1,150 patients, with three hundred beds reserved for major casualties, two main operating rooms, and two auxiliary surgical facilities. These ships, built upon freighter hulls and equipped with Higgins-type LCVP landing craft for shuttling casualties from shore, were held in the "transportation area" of the assault force as evacuation ships. When bed capacity was reached, the ships sailed, to avoid further exposure to air attacks. As a general rule, APHs withdrew out to sea at night, but on occasion they remained anchored about a thousand yards offshore, protected by smoke screens.

Upon U.S. entry into World War II, the Army Transport Services generally assumed responsibility for evacuating Army sick and wounded, carrying them in the hospitals of troop transports. During the amphibious campaigns in the Mediterranean, small craft returning with casualties to transports or hospital ships transferred their patients by litter hoist or by hoisting the ambulance boats themselves to the rail and then transferring the patients directly to the deck. The most expeditious method was to keep one boat, usually a disabled one, permanently rigged for hoisting; ambulance boats would come alongside and directly transfer their casualties to it.[14]

The troopships offered neither comfort nor sufficient care, and there was no guarantee against enemy attack. Consequently, admirals William F. Halsey and Chester Nimitz decided instead to use Geneva Convention–protected ships whenever possible, to evacuate those who needed considerable medical care en route and would be unable to abandon ship without assistance in an emergency. By early 1944, the Comfort (AH 6), Hope (AH 7), and Mercy (AH 8) had been converted and placed into service with civilian crews and Army medical staffs. Ultimately the Army had twenty-six such ships, the majority converted passenger liners or troopships. Two Navy hospital ships had been in commission in 1941; three were added in 1944 and seven more in 1945. During the final phases of the Pacific campaign, tactical doctrine for employment of Navy hospital vessels changed, allowing them to function as mobile, definitive-care combat hospitals rather than as transports only. Specially designed ships of the Haven (AH 12) class were also built to support this concept, which was to continue through the recent conversion of tanker hulls to produce the current Mercy (T-AH 19) and Comfort (T-AH 20). At Leyte Gulf, however, it became apparent that floating hospitals were urgently needed at the objective, especially during the night, when hospital ships were under orders to retire. Two arriving APAs were summarily designated as casualty receiving ships and stationed offshore to provide hospitalization at night. Small escort patrol craft, PCE(R)s, were also used as ad hoc transports for casualty evacuation.[15]

(Official U.S. Navy photograph)

The Korean War

During U.S. Marine landings at Inchon, LST(H)s once again demonstrated their value in immediate medical support of combat operations. Concurrently, two United Nations hospital ships supplemented by five U.S. hospital vessels served as seaborne ambulances, and later as definitive-care platforms. Their original mission was to transport casualties

to Japan, providing care en route, but Korean conditions made them far more valuable as rear-area hospitals. Some shuttled between Korean ports as mobile hospitals; others remained in port for considerable periods conducting clinics similar to those of land-based facilities. Patients were winched aboard from docks or from lighters and landed in helicopters. USS Haven (AH 12), however, arrived in Inchon Harbor without a flight deck; its innovative commanding officer improvised a deck with pontoon sections obtained from the Army, mooring them perpendicular to the anchored ship on both sides and equipping them with warning lights, wind-direction indicators, and firefighting equipment. Rope ladders and temporary gangways provided access. Up to four helicopters could be landed and their casualties brought aboard ship with litter hoists.[16]

USS Haven at Inchon, 1952 (official USN photograph 445542, August 1952)

The Falklands

In 1982, in anticipation of the campaign to retake the Falkland Islands, Britain's Royal Navy requisitioned two commercial cruise ships, SS Uganda and SS Canberra, and refitted them for casualty care. The P&O ship Uganda, already containing hotel, laundry, and other facilities required for patient care, was converted and painted white, with red crosses, in Gibraltar within sixty hours. A helicopter pad was fitted, as well as a ramp for rapid transfer of patients to the main hospital on the promenade deck. Sections of the ship were converted to an operating room suite, an intensive-care ward, a specialized burn-care unit, and a "high dependency" skilled nursing unit, among other facilities. Over the ensuing campaign Uganda's medical staff treated 730 casualties and performed 593 surgical procedures.

The liner Canberra was converted to a troop carrier with a major surgical facility. Original plans called for Canberra to receive casualties, although it did not qualify for Geneva Convention neutrality by virtue of having conveyed troops and equipment to the theater. Unfortunately, after fierce attacks upon the fleet supporting the landing force, the British removed Canberra from the operational area, and elements of its medical organization were hurriedly put ashore at Ajax Bay.[17]

In addition, three ocean survey vessels were converted to Red Cross–identified ambulance ferry ships, which evacuated 593 casualties from Uganda to a neutral Red Cross–supervised aero-medical staging facility 420 miles away in Montevideo, Uruguay. From there they would be evacuated by air to Britain.[18]

Desert Shield/Desert Storm/Operation Granby (Great Britain)

Royal Navy casualty projections in the 1991 Persian Gulf campaign indicated the need for a minimum of a hundred beds in an afloat facility, able to admit mass casualties of all types, initiate their management, and hold them for six days. With no hospital ship then available, the Royal Navy designated the Royal Fleet Auxiliary's air training ship RFA Argus to be that platform. Its flight deck, with five helicopter landing spots and two aircraft elevators, seemed ideal for movement of casualties. The British drew plans to convert the forward hangar to a hospital, in an airtight "subcitadel" (for chemical warfare protection). In three weeks the hospital had been designed, built, equipped, and staffed. Using modular construction techniques procured from a commercial vendor, the exoskeleton of the hospital was lifted to the flight deck in sections, lowered to the hangar deck, fitted together, and moved into position.[19]

Argus arrived in the Gulf with a hundred-bed hospital independent of the superstructure of the ship, including an intensive-care unit, a high-dependency skilled nursing unit, a low-dependency unit, four operating tables in two operating rooms with full support services, and a medical team of 136 men and women. The hospital was also supported by the ship's air department, four Sea King helicopters designated for casualty evacuation, and Royal Navy support and liaison personnel. As a "grey hull" (a combatant in the eyes of international law), Argus could operate in forward areas with unrestricted communication, as ships with Geneva Convention neutrality protections cannot. This concept of afloat tactical medical support afforded significantly shortened casualty-transit time from frontline, at-risk naval units. Indeed, when a boiler exploded aboard the USS Iwo Jima (LPH 2) on 30 October 1990, a number of severely burned casualties were directly transferred to Argus for initial care.

Future Challenges

On 23 October 1983, a terrorist truck bomb carrying twelve thousand pounds of TNT detonated at the headquarters of the Marine Battalion Landing Team 1/8 at the Beirut, Lebanon, airport, killing 241 American servicemen and wounding 112. Sixty-two of the latter were sent to the offshore amphibious ship Iwo Jima, which had a surgical team. Several underwent surgery, and one died. A small group was subsequently sent to the British hospital in Akritori, Cyprus; fifty-six others were evacuated on a four-hour flight, during which an additional casualty died, to distant facilities in Landstuhl, Frankfurt, and Wiesbaden, Germany, as well as Naples, Italy (rather than those in neighboring Israel). As noted by a subsequent flag-level review, the only mass-casualty plan in place had involved Iwo Jima itself. There had been no effective coordinated theater plan for continuity of care, speedy evacuation, and regulation of victims of terrorist attacks—that is, allocation of each to the most capable treatment facility. As the review noted, "had the ratio of killed outright–to–wounded been reversed, so that over 200 casualties had required treatment, rather than fewer than 100, the medical system might well have failed."[20]

Today, if a military force deployed from an offshore, dispersed, and geographically isolated strike group suffered a similar attack, a volume of instantaneously generated casualties of similar magnitude would require prompt and effective care. Any medical treatment system envisioned for geographically distributed operations must provide more timely and competent treatment and evacuation than was offered in Beirut. Given the unpredictable numbers of casualties produced by modern combat and the profound severity of survivable injuries inflicted by weaponry currently in use, it must be anticipated that existing forward facilities may be overwhelmed by "casualty overload." Even over three decades ago, during the 1973 Yom Kippur War, an Israeli Defense Force evacuation hospital in the Sinai Desert, twenty to forty miles from the battle lines, received casualties in lots of from thirty-six to 140, and on one day 440. During the twenty-one days of fighting the facility treated 4,070 wounded, two-thirds of whom were in shock upon arrival.[21]

Distributed Expeditionary Sea Bases

Within a distributed sea-base context, a large volume of suddenly generated casualties could easily overwhelm the limited medical assets envisioned ashore. Furthermore, the improvised explosive devices used in the Middle East have shifted the spectrum of wounding. Advances in body armor and its wide deployment have diminished the incidence of mortal wounds of the chest and abdomen, but greater numbers of casualties with severe blast and fragmentary neurosurgical injuries to the head, brain, and neck, as well as major blood vessel (vascular) injuries of the extremities, may now survive long enough to reach forward combat unit medical staffs. They would ultimately be transported to a sea-based medical support center, if such were available.[22]

In the postulated sea-base medical continuum, the most rudimentary echelon of forward-located medical capabilities may be located at a battalion aid station (BAS), known as medical care Level I. During the Vietnam conflict, timely evacuation to such facilities was often assumed to be impractical, given delays and the occasional inaccessibility of aid stations due to "cantonment," whereby troops lived in one location, were transported by helicopter to fight in another, and were then extracted—and so did not carry their bulky BAS with them. Sometimes medical aircraft evacuating severe injuries bypassed these limited lower-level facilities and flew directly to more advanced (Level II) surgical facilities capable of physician-assisted resuscitation, stabilization, and initial surgery to prolong life. There were also more specialized in-country facilities with subspecialty surgical capabilities, major blood-transfusion resources, and advanced levels of nursing support (Level III).

In the sea-base concept, the large-deck amphibious assault ships within the expeditionary strike groups (ESGs), of the LHA and LHD types, and presumably the forthcoming LHA replacement, the LHA(R), with Level II medical facilities and limited surgical capabilities for stabilizing injuries, will no doubt be the designated "casualty receiving and treatment ships." Heretofore they have carried a standard Fleet Surgical Team augmentation of one general surgeon, an anesthesia provider, and other contingency medical and nursing augmentees. Facilities for Level III, or advanced specialty treatment, as has been available aboard T-AH hospital ships, will presumably be located elsewhere, perhaps in the Maritime Preposition Force (Future), or MPF(F), or in seagoing platforms provided by the other services. It has been suggested that newly designed ships for the MPF(F) will contain extensive medical-support modules with surgical specialty availability, allowing them to replace the aging hospital ships.[23] These modules would require, however, specialized and trained surgical, anesthesia, and nursing personnel, triage and resuscitation space, equipment, and supplies matched to risks combatant personnel are being exposed to, presumably major blood-vessel

injuries as well as life-threatening damage to the brain and spinal cord.

But the large-deck amphibious ships could in reality offer only limited surgical capabilities for stabilizing injuries. The primary mission of these ships is combat operations; the logistic, space, and mobility demands of casualty care cannot realistically be expected to outweigh the combat and combat-service imperatives. Further, despite the purported sixteen "intensive care" beds, the four surgical theaters of the LHA (and the six of the LHD), forty-seven ward beds (suspended from vertical chains), and many hundreds of "overflow beds" (if strike group personnel are off-loaded), space limitations result in the reality that ESG vessels are not supplied with sufficient casualty-support logistics for sustained treatment of large numbers of casualties. More importantly, they lack adequate numbers of the highly specialized medical and, especially, nursing personnel required by the wounds of blood vessels, brain, and spinal cord now being suffered in irregular and urban warfare.

For their part, the two current T-AH hospital ships, although well equipped and quite capable of advanced casualty care when adequately staffed with medical augmentees, are fading into operational obsolescence due to material aging, slow speed, and deep draft (which bars them from littoral waters).[24] Nimitz-class nuclear aircraft carriers not only must primarily serve their operational roles but, in fact, are only marginally capable of in-depth care of multiple casualties, in terms of space, logistics, and personnel.

The LPD-17

The current amphibious fleet recapitalization plan involves the replacement of eleven smaller, aging amphibious landing ships, LPD-4s, and all twelve dock landing ships, LSDs, with new San Antonio–class LPD-17s. The new twenty-five-thousand-ton expeditionary warship—50 percent larger than the next-biggest LPD in the world—is designed to operate in an amphibious patrolling role twenty-five miles off a defended shore and in a nuclear environment. The ship is said to be capable of transporting seven hundred troops, with a surge capacity to eight hundred, and of receiving contaminated casualties through a specially designed triage center off the flight deck. It has two operating rooms, a twenty-four-bed ward, and a stated overflow capacity of one hundred casualties. The limits of its capabilities for combat injuries would be the breadth of available medical personnel and sufficient room available for handling a sudden large influx of casualties.

Limits would also arise from the huge space requirements of contingency medical logistic support. Combat casualties require large quantities of blood for transfusion, including fresh whole blood with clotting components (the latter is not found in either the LHA or LHD frozen blood repositories). During the Vietnam conflict, 10 percent of the wounded required blood replacement, the average being seven units per patient.[25] Thirteen percent of those requiring blood required eleven or more units, some as many as ninety, most of which must be fresh blood with clotting components, to prevent further hemorrhaging. In addition, combat surgical staffs need wide-ranging capabilities not commonly found among surgical generalists, as well as twenty-four-hour availability of skilled nursing personnel and specific logistical support and resupply. Notwithstanding their seemingly advanced medical outfits, the San Antonio LPD and even the projected LSD(X) do not promise manifest, demonstrable value in the initial management of severe combat casualties. Their principal medical role might well be that of secondary casualty-reception facilities for wounded already treated and stabilized elsewhere.

The implications of such medical limitations were demonstrated during Operation URGENT FURY in October 1983, when the United States inserted forces into Grenada. In part because of an inadequately developed and insufficiently communicated joint medical support plan, Army helicopter pilots, unfamiliar with Navy ship profiles and flight decks, deposited critically injured personnel on the flight deck of USS Trenton (LPD 14), a ship with a designated "operating room" but minimal resources for critical care of casualties. One of these wounded, an Army ranger, was in shock due to massive blood loss from a wound through his chest and abdomen. With no blood bank, the general medical officers aboard Trenton were forced to match blood types with volunteer crew members using their identification tags alone, a highly irregular and potentially dangerous practice. They drew blood from the volunteers, literally on the spot, and transfused it warm directly into their critically injured patient before transferring him to the distant USS Guam (LPH 9), the largest medically capable ship in the operational area.[26] Clearly, such older amphibious ships were inappropriate as primary casualty-reception sites.

Modularization

The Navy is analyzing ways to replace stand-alone systems through networking and modularity and to translate them into the basis for changes in the design of warships, at savings in both cost and risk. One such program is the Littoral Combat Ship. Its

interchangeable, self-contained mission-specific modules, with standard interfaces to other modules and shipboard systems, could be swapped to meet various tactical needs—"plug and play." New modules to support additional missions, such as emergency rescue and stability operations or environmental monitoring and support, would likely evolve as well.[27]

As noted, "medical modules" have also been proposed for employment as part of the MPF(F). The ships in this force will be kept in reduced operating status in strategic reserves around the world and activated as necessary. As we have also seen, a modular afloat medical facility (aboard RFA Argus) was successfully used by the British during the first Gulf War. Is this concept of providing robust medical support from the MPF(F) feasible?

Professional and paraprofessional personnel augmentees for MPF(F) modules would need to meet standards of care expected of land-based specialized surgical units and nursing facilities. Likewise, since burns constitute a substantial proportion of wounds inflicted in naval warfare (in the Falklands campaign, 33 percent of the wounds treated in the hospital ship Uganda were burns) ample accommodation must be made for them (as well as for management of patients with blood vessel and neurological injuries).[28] Since these modules would lie in reduced operating status until mobilized, their functional status will require systematic monitoring, their perishable supplies tied to "just in time delivery arrangements" wherever MPF(F) ships are maintained, and their professional staffs identified, funded, and trained to function in that environment.

Missions for the Future

As currently envisioned, the squadron configuration selected for the Navy's Maritime Prepositioned Force (Future) will consist of fourteen ships: twelve new-construction hulls and two existing T-AKR "dense-packed" ships carrying supplies and ammunition. The twelve new ships will be: two T-LHA(R)s, equipped with command and control facilities for a Marine expeditionary brigade; one T-LHD with aviation command-and-control facilities; three modified large, medium-speed, roll-on/roll-off (LMSR) sealift ships; three modified Lewis and Clark–class (T-AKE 1) cargo and ammunition resupply ships; and three mobile landing-platform-type vessels capable of housing 1,100 troops each. These latter innovative vessels should be capable of meeting surface assault requirements without external or aviation support by partially submerging and allowing cargo to float on and off to connector ships.[29] It is anticipated that since the LHA(R)s and LHDs will be conducting forcible-entry and other belligerent operations, they will require reclassification as warships when activated and undergo augmentation by Navy crews. The others will operate, when activated, under the aegis of the Military Sealift Command and be manned by civilian mariners.

From a medical perspective, the first question to be asked, then, is: What are command expectations for the medical assets functioning in a joint sea-base environment? The follow-on questions are: What resources will be necessary to enable the joint/combined-force casualties to reach competent medical facilities within the sea base in a timely manner? In what form will these facilities exist? The answers will not only drive the activity of planners but will ultimately allow more realistic implementation on site during conflict.

The bulk of casualties ashore would be evacuated to the sea base by air, and when required by high-speed, seagoing "connector" vessels. (The LHA[Rs will have no well decks; casualties will have to reach them exclusively by air, or by other as-yet-unproven innovative methods. This may be particularly important during times when weather is too foul for vertical transport. Alternatives such as waterline access or loading platforms alongside may be required). The connectors envisioned (for lift within the sea base as well as long distance) include the Joint High Speed Vessel, the V-22 Osprey, and the CH-53K heavy-lift helicopter. In 2004 the Navy Warfare Development Command conducted an experiment to evaluate the High Speed Vessel as a medical platform. Unfortunately, it found, surgical interventions on board were precluded by high ambient vibration, noise levels, and vessel motion (including severe pounding) at high speeds or sea states—aside from motion sickness of both patients and staff.[30] These findings might clearly impact upon survivability during long-range transport aboard such vessels.

If the ships of the sea base are to be kept continuously available for new incoming casualties without overload, initially treated and stabilized casualties need to be systematically forwarded to higher-level medical facilities, perhaps thousands of miles away. This will require creativity, such as displayed by the British at the Falklands, who used converted ocean survey ships as seagoing ambulances.[31]

Joint Operations: The Need For Integration and Accommodation

Unfortunately, a recent Government Accountability Office (GAO) report on sea basing has identified a lack of "unifying vision" within the defense

community with regard to sea-base development.[32] It notes that individual services appear to be outpacing the Defense Department. For example, the Army is developing its own Joint High Speed Vessel and Joint High Speed Sealift Ship programs. Furthermore, the Army is also beginning to develop its own Afloat Forward Staging Base, intended to provide aerial maneuver for Army forces "from the sea." One option being explored is adding flight decks to commercial containerships.[33]

The inevitable result of such independent activity, however, is the potential for redundancy and a lack of joint coordination, medical support not excepted.

In the absence of an overarching joint experimentation campaign plan, indicates the GAO, many sea-basing investigations—including war gaming, operations analysis, workshops, technological development, modeling and simulation, platform prototyping, and live demonstrations—have taken place across the services, combatant commands, and other defense entities, without the ability to evaluate solutions, including medical considerations, or to coordinate efforts. Likewise, notes the report, there are insufficient modeling and simulation tools available. All this will clearly impact upon doctrine and training as well as any concrete solutions that may be proposed for dealing with the combat wounded. Ultimately, the Navy must coordinate with other services on stable standards for a truly joint and interoperable medical support network.

The Bottom Line

The distributed sea base is to be composed of a series of complex platforms, connectors, and logistics technologies. Logically, it must be driven by a common set of standards, requirements, time frames, and priorities. The advent of the integrated base at sea requires adaptive medical systems "engineering" as well. Within that metaphor, configuration management will be extremely important to ensure connectivity among systems and components—in fact, a "system of systems" approach—for both technical support and logistics.[34] Various ship, airlift, and sealift components for casualty evacuation and treatment will need to interface, and some of them will have to be interdependent. In addition, joint operations from a sea base will require robust logistics technologies, as well as command and control. Premature development of such systems to meet individual service requirements for medical support rather than joint necessities may facilitate initiatives that are duplicative, not interoperable, and possibly incompatible. Ultimately, adverse consequences for combat casualties may result.

The fundamental "bottom line" in any assessment of casualty care, whether single service, joint, or combined, relates to time expended in transporting a wounded person to a proper setting where a constructive medical intervention can be performed. This must dominate every discussion of support systems. (Delay in access to adequate care implies a precipitous decline into the ominous "Triangle of Death," which correlates with entry into an irreversible downward spiral from which there is commonly no return to normal health.) Neglect of this very specific requirement translates into acceptance by operational commanders of increased mortality and morbidity among accrued casualties.

A casual observer visiting a large deck amphibious ship may well be overwhelmed with the abundance of equipment and space available to serve the wounded. Deeper evaluation, however, will reveal that the mere availability of equipment on a sea base ship will not, in itself, insure the availability of the requisite care needed by large numbers of combat wounded. The thrust of any analysis of medical support at sea must emphasize the importance of the time factor, as well as reference to previous empirical adaptations that have been implemented to address the "time to receipt of substantive treatment" issue in various operational theaters.

In conjunction with new and evolving operational approaches that emphasize joint and combined operations, a medical support system and its component material parts must be designed to supply speed, flexibility, and, above all, responsiveness. The corollary is that logistical support, including medical services, must always be adaptive. It must be capable of responding to the unique nature of the conflict in hand and to the operational concepts employed by combatant commanders. In the current context, casualty care must be adapted to geographically dispersed, or "distributed," sea-based operations in the littorals, with minimal medical facilities ashore.

A harmonious vision of sea-based medical support, supported by pragmatic leadership, is an absolute prerequisite to rapid and effective time-sensitive care for the combat wounded during the unpredictable but probably inevitable littoral conflicts of the future.

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