

# Unmanned tele-operated robots as medical support on the battlefield

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## Abstract

- ◆ The use of unmanned telerobotic devices on the battlefield to locate, resuscitate and retrieve casualties under hazardous conditions is becoming possible, but assistance by humans is still necessary.
- ◆ Unmanned battlefield robots are being developed using virtual reality and remote manipulation surgical technologies developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Defence Science and Technology Organisation's battlefield robotics program.
- ◆ These robots would be able to execute a wide range of high-risk tasks across numerous military scenarios, including "real time" life- and limb-saving first aid.
- ◆ This would result in a force-multiplier for the Australian Defence Force, allowing it to use otherwise inaccessible, unique medical capabilities under hazardous conditions.

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The retrieval and immediate treatment of battlefield casualties is hazardous. For example, during the Vietnam War, 1173 US Army medics died as a result of hostile action (3% of total); 69% of them were attached to airborne forces, special forces or infantry.<sup>1,2</sup> However, the advent of sophisticated robotic devices provides an opportunity for wounded soldiers to be retrieved by unmanned rescue vehicles, afforded initial airway, breathing and circulation support by telerobots, and then surgically treated with the aid of telemedicine by a panel of surgical, medical and radiological consultants who can provide advice and diagnosis from the safety of a remote medical facility. The applications of this technology include hazardous battlefield retrievals, urban warfare where traditional aeromedical evacuation is impossible, and remote disaster areas where medical personnel are limited.

This article examines the potential for Australian Defence Force medical support to include tele-operated virtual-reality robot systems for the diagnosis, resuscitation and treatment of distantly located casualties.

## Casualty location and retrieval

Colonel RM Satava of the Defense Advanced Research Projects Agency has described a "digital battlefield" where combat casualty care will include remote sensor intelligent

## Glossary

**Telepresence:** An artificial immersion or presence in a real but distant location. The system involves a special helmet equipped with head tracking devices and 3D displays, and creates an illusion that the wearer is physically present in the remote environment.

**Telemanipulation:** Use of a mechanical device to manipulate objects in a distant environment in real time.

**Telemedicine:** Means to effect a medical outcome when staff are in a different location to the patient.

**Telerobotics:** Use of a telecommunications link to control a robot at a distance.

**Virtual reality:** A collection of technologies allowing personnel to interact efficiently with 3D computerised databases in real time using their natural senses and skills.

## I: Prototype robotic evacuation vehicle (courtesy of Applied Perception Inc, Pittsburgh, US)



systems, telepresence surgery and virtual reality surgical simulations.<sup>3</sup>

Soldiers in the future are likely to be fitted with personal status monitors, which will have a global positioning locator and a suite of vital signs sensors.<sup>4</sup> This will enable medical personnel to instantly locate and assess an injured soldier.

At present, there are no relevant programs for medical robotics on the battlefield. However, the US Army Telemedicine and Advanced Technology Research Centre (TATRC) has awarded Applied Perception Inc, Pittsburgh, US, a research grant to develop a robotic extraction vehicle (REV) — an unmanned armoured 2.5-metre-long, 1600 kg vehicle capable of transporting two casualties on stretchers, complete with life support systems (Box 1).<sup>5,6</sup>

The concept is one of battlefield medics stabilising the injured soldiers and then transporting them to a field hospital in the REV. Prototypes of the REV were demonstrated at the TATRC in March 2005.

An early public demonstration that such robotic manipulation of casualties was feasible occurred in May 2002: Israeli police sappers used a British-made bomb disposal robot to inspect the body of an injured terrorist in Haifa for remaining explosives.<sup>7</sup>

Although advanced robotic resuscitation of combat casualties is not a reality, several research projects show promise. The US Army has identified hypertonic saline dextran as an effective plasma volume expander that can be administered via intraosseous infusion devices in quantities about one tenth of conventional crystalloid solutions.<sup>8</sup> Furthermore, resuscitative drugs could also be administered via the intraosseous route.<sup>9</sup> Currently, placement of resuscitative devices into a patient still requires human hands. Exsanguination from damaged blood vessels is the cause of most battlefield deaths.<sup>10</sup> simple lifesaving techniques such as applying tourniquets may be possible using telerobots. In addition, recombinant activated factor VII has been studied as a means of arresting microvascular blood loss before retrieval from the battlefield.<sup>11</sup> Skeletal stabilisation by means of simple splints could also be achieved by robotic means. Given that 70% of

combat wounds are peripheral<sup>12</sup> (a proportion that is increasing with the use of body armour), this will be a major requirement of robotic casualty care.

Maintenance of the airway and respiratory support are also priorities for immediate treatment of combat casualties, and robotic means of providing such treatment are being investigated.

## Treatment in the field hospital

Casualties are normally evacuated to the military equivalent of an emergency hospital staffed by forward surgical teams. Remotely located, tele-operated surgery or advice could provide an advanced level of specialist medical care using virtual reality technology.<sup>3</sup>

The use of robotic aids in surgery has already been demonstrated, and the da Vinci telerobotic surgical system has been developed to meet the battlefield demands of the United States Department of Defense.<sup>13</sup> A surgeon sitting at a computer console remote from the patient can manipulate robotic arms under stereoscopic vision with high accuracy. The technology allows advanced, minimally invasive, thoracic, cardiac and abdominal surgery. In 1998, a prototype telesurgical system providing a stereoscopic video display of a remote operative field was used in a live animal model (anaesthetised swine) to perform organ excision, haemostasis, suturing and ligatures.<sup>14</sup> However, although this demonstrated the feasibility of a surgeon operating while linked only by electronic cabling to the operative field, most procedures took 2–3 times as long as by conventional means. This was deemed too slow to play a role in resuscitative surgery. For semi-elective procedures such as herniorrhaphies, telesurgery has been successfully performed on sailors aboard US Navy ships, thousands of kilometres from the controlling surgeon.<sup>15,16</sup>

Current systems are designed around a stable hospital environment supported by medical and nursing staff. Further development is required to provide for use in a more rugged

field hospital environment and to meet arduous military medical requirements.

Virtual reality has a stronger place in the diagnosis and surgical planning of operations using 3D clinical data. It also has an increasing place in the training of surgeons who can rehearse unfamiliar procedures without the need to involve live patients.<sup>17</sup> Indeed the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is closely involved in such training with the University of Western Australia and the University of Technology.<sup>18</sup>

## Tele-operated robots in combat casualty care

The ideal situation for medical teams would be for them to be:

- at many different locations, so they are near where they may be needed;
- available on location the instant a casualty occurs; and
- safe and secure in the execution of their task.

Remotely controlled robots located throughout the battlespace (air, land, and water) could provide the ability for medical teams to be in many different locations at any one time. With a tele-operated medical robot beside the casualty, the medical team could begin assessment and resuscitation as soon as the remote communications can be established (which should be almost instantaneously). Importantly, the medical teams are remote from the combat zone and thus safe in their performance of one or more tasks (medical force multiplier).

## Telerobotic medical support in the ADF

For the ADF, telerobotic medical support could be implemented in the following manner:

- Establish a “hub” of specialist military medical teams located remotely from the trauma (possibly in Australian university teaching hospitals).
- When a casualty has been located, these teams can be instantly “teleported” to where they are needed (ie, they use tele-operated robots and virtual reality surgery to deliver their expertise to the remotely located patient).
- These teams could focus on (1) casualty assessment, advice, resuscitation, stabilisation, and evacuation; and (2) hospital level surgical intervention.

The success of a human-in-the-loop system, as proposed here, depends critically on the quality of the human-computer interface. The interface must support situational awareness, complex decision-making, and action at a distance by a human expert.

We propose an interface to the medical robot that combines aspects of several types of systems. A traditional virtual reality system immerses the user in an entirely artificial environment, generated through computer modelling and simulation, and conveyed to the user through a 3D interface. A telepresence system creates an artificial sense of immersion or presence in a real, but remote, location. Telemanipulation extends the concept of telepresence to include more active

real-time manipulation of objects in the remote environment through some mechanical manipulator.

We envisage a system that creates a sense of presence in the remote environment through live stereo video and audio feeds, but augments these with computer-generated, virtual displays. The interface would allow real-time remote manipulation by sensors possessing characteristics that simulate the actual feel of tissues (force feedback). This feedback could have enhanced sensitivity so that it is even more sensitive than when touching real tissue. The interface could also include instruction and supervision capabilities for tasks that can be automated. It is likely that, in some cases, two or more users will simultaneously operate the robot. For example, the roles of navigator and surgeon do not have to be combined. The operators need not be physically present in the same location, but will require a strong sense of co-presence, and will have to work collaboratively towards their goals. Entirely virtual scenarios would be useful for training exercises and for incremental development of the interface.

The combination of simulation and perception generation that is the basis of virtual reality systems could also be used to assist and augment the performance of an operator controlling a complex system such as a medical robot. Naturally, the appropriate types of assistance would need to be determined from a thorough analysis of the situations and conditions in which the robot would be used.

The virtual reality user interface would be designed to place the medical team “at the side” of the casualty, giving them the ability to transfer skills and behaviour from their normal working environment to the new situation. It would also be possible to develop a virtual reality training environment to augment the medical team’s skill base in using the technology, as well as in treating the types of casualties expected in conflict.

Developing this concept further would require the following steps:

- Conduct feasibility studies on the application of telerobots in defence health care, which would include ensuring that robots are capable of:
  - ◆ locating a casualty
  - ◆ giving medical assistance under appropriate tele-operation
  - ◆ assisting in safe evacuation of casualty.
- Develop the teleremote virtual reality tools for the surgeons.
- Develop the communications and protocols to allow safe long-range use.
- Develop hospital level surgical robots for the Forward Surgical Teams.
- Develop the appropriate military medical doctrine.

Australia has the capacity to use current research and development programs to achieve this goal (Box 2). The proposed capability is simply the novel application of existing and emerging technologies, rather than pursuit of a massive program starting from scratch.

The Defence Service and Technology Organisation (DSTO) has a number of tasks looking at different aspects of robot

## 2: How to proceed in implementing telerobotic medical support in the ADF

- Use the technology and research base in Australian universities and teaching hospitals as part of the robot technology base used by the Defence Science and Technology Organisation (DSTO) and the Defence Health Service.
- Use Australian industry to devise the product to be deployed.
- Technology and doctrine to be developed in parallel.
- The development programs should be as follows:
  - ◆ DSTO develops the tele-operated robot medical capability
  - ◆ The Commonwealth Scientific and Industrial Research Organisation (CSIRO) develops the virtual reality user interfaces
  - ◆ DHS develops the medical doctrine for capability
  - ◆ DHS also sponsors development of the supporting medical technologies (eg, virtual orthopaedic computer-controlled navigations tools).

technology, with Weapons Systems Division taking the lead in developing robots for use in combat as a weapon system.

## Conclusions

Tele-operated robot technology has the potential to solve logistic problems such as the provision of sufficient medical support with adequate expertise in remotely located areas and with adequate protection in hazardous environments.

Through the collaborative efforts of the DSTO, CSIRO and the Defence Health Service, Australia is capable of developing the technology and protocols required to give the ADF a tele-operated remote medical capability.

DSTO is already capable of developing the tele-operated remote medical system and we believe the ADF should develop a medical robot capability.

The DSTO would be the program's main developmental centre, with DHS taking responsibility for development of protocols for using the technology. Programs to equip medical personnel with the skills to operate this technology would be necessary, bearing in mind that these robots are merely a tool for use and enhancement of casualty care, and not a replacement of clinicians.

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## Competing interests

None identified.

## Editorial comment

Increasingly, the battlespace is becoming robotic, with commensurately fewer human personnel. Ultimately, robots will be able to think faster, analyse multiple complex tasks faster, move more quickly, withstand greater *g* forces, survive more extreme temperatures, and so on. Nevertheless, there are problems with medical robot technology. These include:

- cost: even with its impressive budget, the United States Department of Defense has found that this technology is almost prohibitively costly to establish and similarly expensive (about 20% of capital cost) to maintain, although cost-benefit may be attained over time as technology changes so rapidly
- sophistication of communications needed (bandwidth, uninterrupted service)
- time delay of transmission over long distances
- delivery of the robot to the patient in a suitable environment for it to work
- weight and size of the robots, particularly in a deployed situation
- approval by health regulatory authorities for use of this technology
- accreditation of the manufacturers, the procedures to be performed, the operators, etc.

In addition, use of robots raises questions of soldiers' consent to be treated in this way.

None of these problems are impossible to solve, and this area is rapidly changing. The Australian Defence Force will need to monitor advances in this area, and it is important that the proposals by Lucas et al be included in the JP 2060 Phase 3 Project Definition Study for inclusion in the Future Health Capability. The major problem for the ADF will be cost — it is difficult to see this technology in use in the ADF within the next 10 to 15 years.

Aspects of this technology could reduce the medical footprint, especially for critical surgical specialties. Clinically, the use of robotics requires further research if it is to improve patient outcomes. However, it can only be assumed that the support staff required would approximate current staffing levels. The use of robots in medical retrieval roles is plausible, especially in the asymmetrical battlefield in which we increasingly find ourselves operating.

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