Blood supply to the ADF: current arrangements, limitations and future strategy

Captain Kevin A Rickard, AM, RFD, RANR(Rtd)

THE ADMINISTRATION of an urgent blood transfusion to a member of the Australian Defence Force in circumstances of battlefield medicine has been rare in the ADF since the time of the war in Vietnam. However, with an increasing number of active deployments and hazardous peace keeping missions, the entire issue of blood transfusion medicine in the ADF and the important role of blood supply to the ADF should be under regular and active consideration.

Synopsis

- The ADF relies on the Australian Red Cross Blood Service (ARCBS) for its blood supply needs. This system is adequate during peacetime, but might be overburdened in circumstances of sudden conflict with heavy casualties.
- Safety in blood transfusions requires expertise in collecting, testing, storing and administering blood. ADF capabilities in blood transfusion medicine are limited.
- Service personnel on deployment could be considered as a "walking blood bank", capable of supplying blood on demand locally, but there are important safety limitations to this approach. For example, the window period between infection and antibody production means that serological tests for HIV will not detect all infective donors. Also, managing donors and blood collection and testing in the field is not a trivial matter.
- Frozen red cells are a more durable alternative to fresh blood, but there is no Australian source of frozen blood. The ADF might be able to source frozen red cells overseas, but would need to acquire technology and expertise for thawing and washing the cells before use.
- The ADF could consider starting an ADF Blood Bank, based on donations from its own personnel, perhaps in cooperation with the ARCBS, as a way of increasing the supply of blood and improving its transfusion medicine capabilities.
- Whatever solution to future blood supply needs is envisaged, the ADF needs to review and update its policies in relation to blood supply and transfusion medicine.

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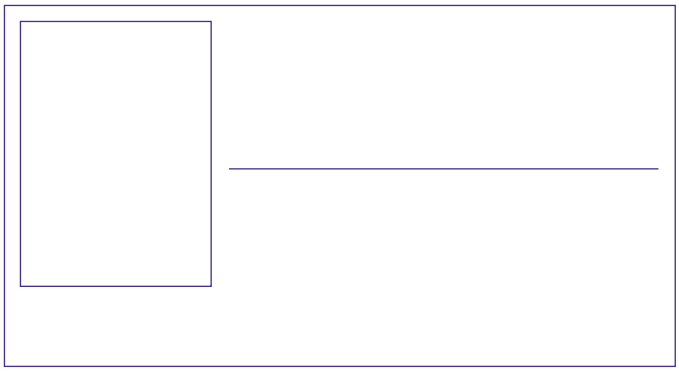
Blood components, their indications and use

Whole blood contains the red cells and plasma components of donor blood. Platelets and white cells remaining in stored blood are usually non-viable after a few days. Whole blood is indicated for those patients who have a symptomatic deficit in oxygen carrying capacity combined with hypovolaemia sufficient to be associated with shock. Whole blood is now rarely used, as transfusion of specific blood components is more effective and safer.

Red cell concentrates are prepared from whole blood by removal of most of the plasma as well as platelets and white cell fractions. Adenine saline is added. Red cell concentrates are preferable to whole blood for treating patients with a symptomatic deficient of oxygen carrying capacity. They are buffy coat poor and have a haematocrit of 0.50–0.65.

The intended recipients of blood or blood components must be properly identified before the transfusion is started. The plastic blood container should not be vented and a standard filter should be used in the transfusion line. Blood or components should be mixed by inversion before use and no medication or solution should be added to an infusion through the same tubing, other than 0.9% sodium chloride solution for injection, ABO-compatible plasma or 4% albumin solution. Electrolyte solutions containing calcium should never be added, as the calcium molecule will cause the citrated anticoagulated blood to clot. The sterile integrity of the container must be preserved at all times and the rate of administration needs to be indicated by the patient's clinical condition, but in general no more than 5 mL per minute for the first 15 minutes of the transfusion.[1]

The label on the blood container indicates the donor ABO group and, where appropriate, the Rh type (Rh-negative indicates negative for both D and weak D reactions). Each Australian Red Cross Blood Service (ARCBS) donation has been tested and found negative for antibodies to HIV, hepatitis B, hepatitis C, HTLV-1 and syphilis.[1,2] Nucleic acid testing (NAT) has been implemented to reduce the window period between infection and the development of detectable antibodies, particularly for HIV and hepatitis C. In addition, because of the

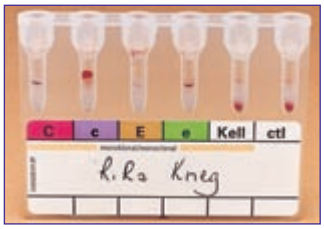


1 The DiaMed system

a) The sampler with on-board incubator.

b) DiaMed cards loaded into centrifuge

c) (below) DiaMed cards demonstrating reactivity against Rh antisera but no reaction with Kell antiserum.



concerns related to Creutzfeldt–Jakob disease, there is an embargo on potential donors who have had extended periods of residence in the United Kingdom between 1980 and 1996.

Fresh frozen plasma is separated and frozen within eight hours of collection of whole blood. A bag of fresh frozen plasma (220 mL) contains all the coagulation components of whole blood. Fresh frozen plasma is indicated for patients with coagulopathy who are bleeding or at risk of bleeding, when specific therapy with vitamin K is inadequate or inappropriate, or when a specific factor component is not appropriate. Fresh frozen plasma contains about 200 U of factor VIII or factor V. It is a non-virally activated product, contains a relatively high load of sodium and may produce circulatory overload problems if administered excessively.[1]

Platelet concentrates are separated from a single unit of whole blood. Single-donor platelet collections result in about 6×10^{10} platelets suspended in 40–60 mL of plasma. Platelet concentrates must be agitated gently and continuously on a horizontal shaker and stored at 20–24°C.

Platelets are indicated for treatment of patients when bleeding is due to severely decreased platelet production or to functionally abnormal platelets. Platelet transfusions are not usually effective or indicated in patients with rapid platelet destruction due to immune-mediated mechanisms (eg, idiopathic thrombocytopenic purpura). They are of value in consumption coagulopathy and dilutional thrombocytopenia. They can be given prophylactically after chemotherapy and in selected cases of postoperative bleeding (eg, when a platelet count is less than $40–50\times10^9$/L.[3]

Platelet concentrates are considered in terms of dosages. Although there is no standard dose for platelet trasfusions in Australia, it is routine practice o administer four single-donor units (eqivalent to $2.5–3\times10^{11}$ platelets). Platelet collection by cytopheresis does allow collection of more specific platelet concentrates for a particular patient. The type of platelet product and availability often determine the precise dose of platelets administered. In general, high dose platelets result in a better platelet transfusion increment and in increased transfusion intervals.[3]

Laboratory pretransfusion testing – serological safety

It is beyond the scope of this article to discuss blood bank serology in detail.[4] All recruits to the ADF have their ABO blood group and Rh status tested, often by laboratory services at the recruit training establishment. This vital information is contained in the service person's medical records and on their "dog tag" on deployment. Before service personnel receive or donate blood, ABO and Rh group are reconfirmed.

When cross-matching potential donor blood with a recipient, it is better for the donor's blood to be within the same blood group system as the recipient or to use O-Rh negative blood. However, in all cases, a laboratory cross-match test should be performed, whereby donor red cells are mixed with the recipient's serum under varying conditions, in saline or with an indirect Coombs reagent. These tests may be performed by a tube spin method or in a gel column system, such as the DiaMed system currently employed by the ADF (Box 1).[5] Agglutination of the mixed serum indicates incompatibility and that the donor must not be used for this recipient.

General hospital blood banking systems now employ computerised methods whereby potential recipients are screened for the presence of antibodies in, say, the Rh, Kell or other systems by testing the recipient's serum against a panel of cells containing all the more common antigens. Freedom from agglutination in this system indicates the absence of antibody and obviates the need for a specific donor–recipient cross-match test. If recipient serum agglutinates in the screening test, further cross-match tests will be required to identify which antibody or antibodies are present (eg, anti-C or e). Blood lacking these antigens is then chosen and a physical cross-match is performed to ensure compatibility.

The system of recipient screening for antibodies is probably unnecessarily complicated for the ADF, which is composed of a healthy young adult population who are unlikely to have antibodies that are usually stimulated by a previous transfusion or pregnancy. However, with the increasing number of women in the ADF and the possibility of previous pregnancies, an iso-antibody is an increasing possibility. Most importantly, the ADF must take all measures to avoid the administration of Rh-positive blood to an Rh-negative female because of the risk of subsequent rhesus immunisation and the likelihood of rhesus incompatibility with future pregnancies, or incompatibility at a time of future transfusion.

Blood supply – the ARCBS contribution

The use of ARCBS donors

The reliable supply of blood and blood products is essential for high quality emergency and definitive health care both in

peace and on active operations. This supply involves each of the services, service and civilian transport agencies, civilian health facilities and the ARCBS.[6] This policy has been confirmed by the ARCBS and was implemented in Operation BEL ISI in Bougainville and in Operations WARDEN and TANAGER in East Timor.

For all practical purposes, the ARCBS supplies the ADF with red cell concentrates on a request basis. The ARCBS has been providing these red cell concentrates from the blood transfusion service closest to the deployment area, supplemented when necessary by resources from other transfusion services within the ARCBS. Red cell concentrates currently being supplied are blood group O-Rh negative and O-Rh positive, collected and screened according to the Australian national guidelines for the selection of blood donors.

Red cell concentrates supplied by the ARCBS must then be stored and transported according to national standards for blood storage[7] (ie, under refrigeration conditions at 2–6°C in an electronically alarm-monitored refrigerator able to safely operate within an ambient temperature of 10–43°C). Blood not stored continuously under these conditions is not suitable for use. Under controlled refrigeration conditions, red cell concentrates have a shelf life of 42 days, according to ARCBS standard operating procedures.

Although Health Policy Directive 703, *Blood supply* (April 1994), mentions that blood and blood products required by the ADF may include platelet concentrates and plasma components (immunoglobulins, anti-D immunoglobulin, clotting factor component concentrates and fresh frozen plasma), these products are not regularly supplied by the ARCBS. The immunoglobulins and clotting factor concentrates are relatively easy to store, as they can be kept under domestic refrigeration conditions. Storing platelet concentrates is more difficult, as they require constant agitation and have a viable storage life of only five days. The ARCBS is prepared to provide platelet concentrates to the ADF as needed, but transporting them over long distances to deployed units would be problematic.

Fresh frozen plasma needs to be stored at or below –25°C in graph- and alarm-monitored freezers.[1] Because of these stringent storage conditions, there is limited availability of fresh frozen plasma in the ADF.

Blood supply – the ADF contribution

The use of ADF donors — the "walking blood bank"

If an ADF service person required an emergency transfusion during a remote deployment, it is possible that the best source of donor blood would be from another member of the unit. Each unit can be thought of as supplying its own "walking blood bank". However, there are real difficulties with this concept. Collecting blood for transfusion in a sterile manner, serological testing, cross-matching, documentation, safe storage and administration of blood are tasks that require training and experience which may go beyond the scope of ADF health service personnel in a conflict or emergency situation. Reade (see pages 65-70) writes further of the difficulties with the walking blood bank concept.[8]

Recruitment and bleeding of potential ADF donors

To recruit potential donors in an emergency, the approach may be to collect from so-called universal donors (ie, O-Rh negative), or (because universal donors are so rare) to collect blood from donors of the same blood group as the wounded individual. Whole blood in 400–450 mL lots would be collected from individual donors into plastic giving sets in a sterile manner after a clean venepuncture of the donor's antecubital vein. This blood would be labelled with the blood group and donor's name and stored at 5°C until administered.

Cross-matching

Life-threatening haemolytic transfusion reactions may occur if there is an incompatible transfusion (Box 2). The initial step would be to check the blood group of the donor and the recipient. For the donors this would be done before any blood is collected. Ideally, the donor blood of the appropriate group should be cross-matched with the recipient for compatibility. Both the blood grouping and cross-matching may be done using the gel column technique (DiaMed system), or by the bench top tube technique. An indirect antiglobulin test requires incubation of donor cells and patient serum, washing and then addition of a Coomb's reagent, all somewhat cumbersome in an emergency situation. The indirect antiglobulin test is incorporated in the DiaMed system, but in an emergency situation a saline "quick spin" method, checking for ABO incompatibility, may be all that is possible. Health Policy Directive 710, *Emergency cross matching at sea*, outlines basic techniques using a simple tile or tube system.[9]

Blood safety — haemovigilance

One of the biggest problems in the whole area of blood transfusion medicine over the past 20 years has been the risk of viral contamination of blood and blood products, and the management of the complications in virus-infected recipients. Even in the field situation, there is still a duty of care required to ensure blood safety. The difficulties created by the "window period" of undetectable but transmissible bloodborne infections are well recognised.

There are screening kits available to test for HIV, hepatitis B and hepatitis C. These tests would need to be applied to any donor blood collected in the field before transfusion. The tests are enzyme immunoassays, where whole blood is added to reagents in the wells of the test kits. These test kits do have Therapeutic Goods Administration approval for use by ADF personnel under field conditions. Indeed, the Abbott Determine HIV-1/2 assay (Abbott Laboratories, Tokyo, Japan) is a spot test that is 99.9% specific for HIV antibody and is approved as a primary test by the HIV National Reference Laboratory. The window period is similar for all tests based on HIV antibody detection, depending on the time taken by

the individual to seroconvert — usually about three weeks, but possibly as long as six months. The latter situation of the "immunosilent" donor would present a problem for the ADF under field conditions.

Using nucleic acid testing (NAT) for HIV DNA or HIV RNA, those who are infected will be detected within a few days of infection.

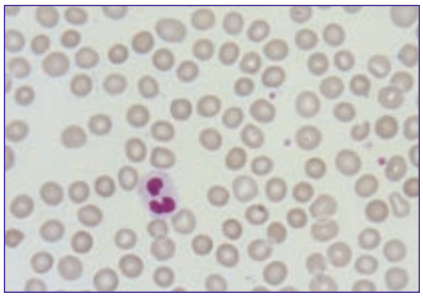
The average window periods for antibody (ELISA) or antigenaemia (NAT) testing for HIV, hepatitis B and hepatitis C are shown in Box 3.

Blood administration

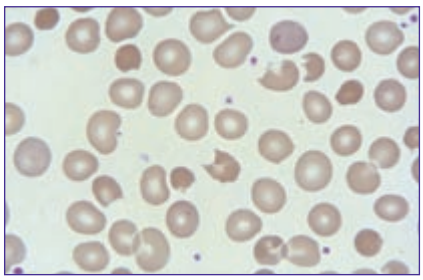
When all of the above is completed to the satisfaction of those involved under what would almost certainly be difficult circumstances, the next step would be the administration of the blood units to the donor, perhaps at Level 2 but preferably at Level 3 or Level 4 facilities. It must be said that if only one unit is thought necessary, it is probable that the recipient does not need a blood transfusion at all. While the blood was being administered, the recipient would need to be kept under medical observation, and if alarming signs or symptoms develop that might be associated with the transfusion then the transfusion would be stopped.

2 Haemolytic transfusion reaction

a) Normal blood film



b) Haemolytic blood film, as may be seen with an incompatible transfusion, showing spherocytes and fragmented red cells.



(Haematoxylin and eosin stain; original magnification × 100)

Other ADF blood supply sources

Other potential sources include the use of frozen red cells, host-nation donors, blood salvage, and possibly the creation of an ADF Blood Bank.

Frozen red cells

Frozen red cells are used in the US military and have been used by the British and other armies in recent European conflicts. An obvious advantage is that frozen red cells are suitable for long term storage, which overcomes the wastage problem inherent in conventional red cell packs. Certainly frozen red cells, after thawing and washing, have good recovery values and in vivo survival characteristics. Moreover, the fact that they have been stored frozen for some time can be used to overcome the window period problem by delayed donor testing.

Implicit in the use of frozen red cells is a profound working knowledge of the techniques involved, namely methods for the effective glycerolisation of red cells and their freezing and storage.[10,11] Storage does require a foolproof labelling system, which may need to be viable for several years. Further, red cell thawing, washing and preparation for transfusion requires specialised technology (eg, the Haemonetics cell washing system), which would need to be available and transportable within the ADF. The skill and expertise to perform these tasks would need to be readily and generally available in the ADF.

However, the ADF's major problem with the use of frozen red cells is lack of a local source. The ARCBS does not produce frozen red cells, except in a very limited capacity for maintenance of very rare blood group systems. The US military might provide an alternative source of frozen red cells.

Blood salvage

Intraoperative blood salvage is used in some major hospital environments in Australia, where there is considerable expertise available in the techniques involved. The procedure is attractive in some operative areas, but certainly contraindicated when there are infective operating fields and probably also when there is extensive bone trauma and the risk of fat embolism. Accordingly, in many potential ADF scenarios it is doubtful whether perioperative blood salvage is a viable option.

Blood substitutes

With increasing concerns over blood safety many synthetic alternatives are under development.[12] These include soluble haemoglobin derivatives, perfluorocarbons, platelet substitutes and so-called "stealth" red cells, which are cloaked with polyethylene glycol to suppress antigen expression. At least two products, the perfluorocarbons and a cross-linked haemoglobin, are likely to be licensed in parts of Europe and the USA for clinical use in the not too distant future. However, their exact role in clinical transfusion medicine is yet to be clarified.[12,13]

3 Average window period (days) for tests of HIV, hepatitis B and hepatitis C infection

	HIV	HCV	HBV
ELISA	22	70	70
NAT	11	35	Not available

The window period is the time between the moment of infection and the moment when the infection can be detected by testing.
ELISA = enzyme-linked immunosorbent assay.
NAT = nucleic acid testing.
Source: M Dean, Australian Red Cross Blood Service, personal communication.

Host-nation donors

Most countries where the ADF may find itself involved in military or peacekeeping operations do not have a safe donor system and a viable transfusion service with fully operational blood banks. Donor

blood from these nations, if it is available at all, is likely to carry risks of infection that would be unacceptable to the ADF.

An ADF blood bank

The ADF could end its reliance on the ARCBS by creating its own blood bank, maintained by blood donations from service personnel. Recruiting donors might not be difficult: many personnel are already blood donors and more might be persuaded to donate blood that was intended to assist wounded colleagues. This ADF blood bank would require collection and storage facilities as well as access to transport, which, within Australia, might be controlled by RAAF logistics.

An ADF blood bank would be a ready and reliable source of blood to the ADF, and the operation of the blood bank would provide valuable experience in the handling, labelling, testing and storage of blood and blood components. This expertise would then be immediately available to the ADF in time of need or crisis.

To meet the regulatory standards of the National Association of Testing Authorities and the Therapeutic Goods Administration, and to supplement the technical expertise of the ADF Health Service, an ADF blood bank could perhaps be operated as a satellite of a State ARCBS. Under such arrangements, the sophisticated testing of donor units could be performed at the "mother blood bank" with relevant ADF Health Service input into these laboratory procedures. A memorandum of understanding could be drawn up for this purpose, setting out the relevant contracts between ARCBS and the ADF Blood Bank and meeting the relevant medical/ethical responsibilities. However, the clear understanding would be that ADF has "first call" on blood derived from ADF donors, while ARCBS would supervise and hold a level of responsibility in the area of haemovigilance.

The major advantages of such a system for the ADF would be a ready, continuing and immediate supply of blood and blood products during any conflict, and the continuing involvement of health service personnel in collecting, managing and distributing blood resources. It could be argued that the use of ADF donors for an ADF blood bank might reduce the pool of donors available to the ARCBS, but, in a bilaterally operated system with ARCBS-controlled haemovigilance, this would not necessarily be the case. The ARCBS contribution to the ADF blood bank could be interpreted as an altruistic contribution to Australian defence needs, with material benefits for both parties. The concept of an ADF blood bank is at least worthy of an ADF feasibility study, since the matter of blood supply to the ADF is of such extreme national importance.

The ADF blood supply system: an audit or inventory control

The ARCBS presently supplies 15 units per month of group O-Rh negative and O-Rh positive blood to the ADF for use in the Bougainville deployment and 20 units per fortnight for use in the deployment in East Timor. In East Timor, these blood resources are potentially used for personnel in United Nations forces other than ADF members. In both East Timor and Bougainville, blood may be given to seriously injured or wounded indigenous people at the discretion of local commanders.

In Australian-based operations, 20 units of group O Rh-negative blood is requested for operation TANDEM THRUST each year — 10 units to be located on HMAS MANOORA and 10 units to be located at a blood bank in the Shoalwater Bay area.

The use of such resources merits the development of an audit system by a control group or ADF blood program coordinators. Such an audit would take into consideration the manner in which blood products were used or discarded: duration of storage, condition of storage, terms of collection and tracking of the blood through the ARCBS and ADF systems. This information would be of value for controlling subsequent ordering patterns and minimising blood wastage.

Discussion

The resuscitation of people who have sustained major trauma often requires the use of blood products, especially red cell concentrates. As ADF personnel are always at risk of trauma, the ADF must carefully plan its blood supply and maintain expertise in transfusion medicine. Because several life-threatening illnesses can be readily transmitted by blood transfusion, safe transfusion practice has become a major medicolegal issue. The appropriateness of blood transfusion medicine is under continuing review, with an increasing input from regulatory authorities such as the Therapeutic Goods Administration. The ADF cannot be passive in this area, but must prepare for the possibility of increased blood supply requirements under increasingly rigorous safety standards in future.

The current arrangements for blood supply to the ADF rely totally on the generosity and goodwill of the ARCBS. The number of blood units required by the ADF is currently small, but the ARCBS is facing an increasingly difficult struggle to maintain donor numbers. Therefore, the ADF should consider two questions. First, can it justify its heavy reliance on the ARCBS? Second, how would the ADF manage a sudden surge in the need for blood in a serious conflict? The second question especially needs very careful examination, not only by the ADF Health Service, but also by strategic commanders. It is written in the United States Armed Services Blood Program that "The planning and execution for the effective management of blood and blood products is a continuing, dynamic process requiring a coordinated, highly responsive system that extends from CONUS [high command] to the battlefield".[14] From the ADF perspective, this statement is extremely challenging. The ADF's reliance on the ARCBS places aspects of the provision of blood products outside its command structure.

However, within the Australian health care system, under current medical and customs regulations, there are no imme-

diate alternatives. Some of the possible alternatives that could be developed have been explored in this article.

Within the current system, perhaps the most important aspect that requires new emphasis and continuing education is in building the skills of ADF clinicians to determine when blood transfusion is clinically appropriate: its indications, safety, methodology, benefits and possible side effects.[16,17]

Aside from improving the efficient use of blood by clinicians, other potential means of coping with increased demand for blood which have been examined in this article are the "walking blood bank", the use of frozen red cells and the possibility of an ADF Blood Bank.

Both the practicalities of the walking blood bank and the medicolegal implications of the limitations of serological testing cast doubt on whether such an approach is justified within the ADF.

Frozen red cells have now been in use internationally for more than 20 years. A great deal of expertise and a simplified approach to their preparation, washing and use has been developed.[10,11] The US Armed Services Blood Program relies heavily on frozen red cells and large budgets have been invested to service the logistic implications. However, what is to be the ADF source of frozen red cells? An immediate possibility is to look to the US armed services for the provision of frozen red cells to the ADF in a major conflict situation. This would necessitate the ADF at least acquiring the skills and equipment for red cell washing. This is not altogether an outlandish proposal, as the British Army in Bosnia was using red cells provided by units of the Netherlands Transfusion Service. However, the ADF would need an exemption from Australian Customs regulations that prohibit the import of frozen red cells.

Perhaps the most realistic approach to the vexed issue of an expanded blood supply to the ADF is to explore the possibility of an ADF Blood Bank. Such an activity could operate within the framework of our regulatory systems and would satisfy the notion of national self-sufficiency in blood supply.

It might also do something to address the apparent decline in knowledge and numbers of laboratory scientific staff in the ADF. This appears to be an unfortunate side effect of the increasing move towards "civilianisation" of health care services, and the perceived need to increase numbers of "conflict-type" personnel in the ADF. This trend could have disastrous consequences in the field of laboratory transfusion medicine, where a mismatched or incorrect transfusion can have fatal consequences. A critical cadre of uniformed personnel must be maintained in the ADF to retain the skill, expertise and quality needed for the laboratory aspects of blood transfusion practice.

Blood supply and blood transfusion medicine are critical matters for the ADF, and should be kept constantly under review. A viable mechanism for regular examination of the issues needs active consideration, perhaps by forming an appropriately constituted ADF Transfusion Medicine Steering Group. Transfusion medicine requires wider recognition not only in the Defence Health Service but also in the command structure of the ADF, and there must be increasing liaison between these groups to improve many aspects of this vital area of medical practice in the ADF. One urgent need is to examine the interface between the ADF, ARCBS and Commonwealth instrumentalities (eg, Therapeutic Goods Administration and Solicitor General), and another is to examine the future provision of blood and blood products in times of escalating conflict.

An ADF blood program organisation is needed to address these issues, composed of relevant interested parties with the necessary expertise. Such an organisation should have the necessary financial support to meet regularly, and the capacity to present its findings to the highest levels of the ADF, as the responsibility for blood supply is not only the responsibility of the Defence Health Service. It should consider:

- Contingency plans for the management of surge demands for blood products.
- Alternatives to existing blood supplies and technologies.
- Matters of liability and responsibility of ADF health service personnel.
- Schemes to retain appropriate uniformed laboratory expertise, and continuing training and education of this group.
- Guidelines on haemovigilance and inventory control for 'blood products in the ADF.

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