

PIONEERS AND PATHFINDERS

Canadian Surgeons and the Introduction of Blood Transfusion in War Surgery

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Canadian surgeons serving in the Canadian Army Medical Corps in the First World War were responsible for introducing transfusion in the management of war casualties to the British Army. They were uniquely placed to do so by a coincidence of circumstances. They were aware of developments occurring in the field of blood transfusion in the United States, which was at the time leading the research and development of transfusion as a therapeutic measure. The ties between Britain and Canada in 1914 were such that Canada entered the war immediately, and Canadians served closely with the British, volunteering promptly and in large numbers. Britain, by contrast with the United

States, had little interest in or expertise with blood transfusion. Thus, Canadian surgeons went to war aware of the value of blood transfusion and with some who had actually learned how to use transfusion. They arrived to find no interest or expertise on the part of their British colleagues and had to work hard to convince them of the merits of blood transfusion in the management of hemorrhage. Their efforts were reinforced by the arrival in 1917 of American surgeons bringing their experience with transfusion. By war's end, blood transfusion was generally accepted as the treatment of choice for severe blood loss.

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THE SCIENTIFIC BASIS of blood transfusion practice is generally regarded as having its origins in Landsteiner's¹ discovery of the immunologic phenomena defining the biologic basis of the blood group system we now know as *ABO*. Before that time transfusion of blood was the purview of a few dedicated practitioners, especially obstetricians (most notably James Blundell) dealing with patients in extremis from postpartum hemorrhage.² The procedure was fraught with practical problems, which discouraged its more general use, including ill-understood, sometimes fatal, reactions and, especially, a frustrating propensity of blood to clot and impede the procedure.³

Landsteiner's discovery set the scene for the development of simple methods for the determination of compatibility. At the same time, there was interest in the practicalities of transfusion, particularly in the United States, with the invention of a variety of ingenious devices for the rapid transfer of blood from donor to recipient before it had the chance to clot.⁴⁻⁶

Although transfusion was gaining acceptance in the United States as a therapeutic measure in the prewar years, interest in Europe and particularly Britain was almost nonexistent.^{3,7}

It fell to Canadian surgeons, particularly Lawrence Bruce Robertson,⁸ to bridge the gap between the gathering interest in transfusion in the United States (and Canada) and the indifference of the

British to its possible value in the management of hemorrhagic "shock" in battle casualties.

STATE OF BLOOD TRANSFUSION, 1900 TO 1914

United States

The first to use transfusion with any frequency in the United States was the Cleveland surgeon GW Crile who had become convinced as early as 1898 that the fluid of choice for the treatment of hemorrhagic shock was blood.⁹ Alexis Carrel, a French surgeon also working in the United States and with a particular interest in vascular surgery and transplantation, had developed a technique for direct (donor) artery to (recipient) vein transfusion using surgical anastomosis.¹⁰ Crile adapted Carrel's method and developed simpler direct artery to vein transfusion using a cannula to link the vessels.^{2,11}

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doi: 10.1016/j.tmr.2007.09.004*

Both techniques presented practical difficulties in the form of demanding surgical skills and an inability to determine the amount of blood transfused. This led to attempts to devise transfusion devices that would allow measured transfusion of blood between donor and recipient sufficiently quickly to effect adequate transfusion before clotting could occur. Numerous such methods or devices were invented.¹² Three in particular were widely used and are frequently cited by the surgeons practicing transfusion in the early years of the war. Lindeman at Bellevue Hospital, New York, used multiple syringes.⁴ Unger,⁵ also working in New York, developed a 4-way stopcock connected to a large syringe, which allowed repeated transfer of blood from donor to recipient with saline flushes between transfers of blood. In Boston, Kimpton and Brown⁶ used a cylinder, coated in paraffin to delay clotting, and positive pressure to speed up the transfusion. Disadvantages of all these devices included requiring the presence of the donor(s) and multiple operators.

The potential of citrate as an anticoagulant for blood transfusion was recognized as early as 1893,^{13,14} but it was not until 1914 to 1915 that the successful transfusion of citrated blood was actually reported (almost simultaneously in Belgium, Buenos Aires, and New York).¹⁴ In 1915, Weil¹⁵ and Lewisohn¹⁶ in New York established the conditions for and feasibility of transfusion of stored citrated blood, greatly simplifying the procedure.

Although the immunologic basis of what we now know as the ABO blood group system was described in 1901,¹ it was some years before the practical implications for transfusion and the prevention of major incompatible reactions were pointed out.¹⁷ However, this had little immediate influence on practice.¹⁸ It was only several years later that the work of Ottenberg^{19,20}, who developed the concept of the "universal donor," took hold.² Furthermore, there remained confusion in the blood group nomenclature, and the simple (I-IV) system devised by Moss²¹ was widely adopted: I (AB), II (A), III (B), and IV (O). (The ABO nomenclature was not universally adopted until 1927.¹⁸)

Thus, by 1914 in the United States, blood transfusion was being used with increasing frequency, a variety of practical methods for transfusion had been devised, the importance of pretransfusion testing and ABO blood groups was beginning to be appreciated, and discovery of the

use of preservatives leading to transfusion of predonated stored blood was imminent.

Britain

The situation of blood transfusion in Europe was in sharp contrast to that in the United States. There was little interest in transfusion, which was an uncommon, even rare, event, usually using direct vessel to vessel techniques; the various devices in use in the United States had apparently not been adopted in Europe by the beginning of the war.⁷

In Britain, in spite of the pioneering work of Blundell and his contemporaries (mainly obstetricians faced with catastrophic postpartum hemorrhage), transfusion of blood became of dwindling interest in the latter decades of the 19th century. The practical difficulties of transfusion, the professional disdain in which "specialists" such as obstetricians were held, and the rise in the status of and academic interest in experimental physiology conspired to promote a search for alternatives to blood at the expense of blood transfusion.³ Opinion on the whole favored isotonic saline as the resuscitative fluid of choice (and as late as 1916, the physiologists were still advocating the use of nonblood colloid agents such as 6% or 7% gum acacia in 0.9% saline). Consequently, the British entered the war with saline as their answer to "hemorrhagic shock." It is ironic that Crile spent a month in 1895 at the physiology laboratory at University College, London (which was active in this field of research), and, on his return to the United States, conducted experiments on animals, which convinced him that saline was of no lasting value in blood replacement and that only blood would remain in the circulation.³

The lack of interest in blood transfusion in prewar Britain is highlighted in 2 Editorials. One in the *British Medical Journal* in 1907,²² commenting on the article by Crile,¹¹ although conceding that excellent results were obtained in some cases of shock, concluded, somewhat surprisingly, that "surgeons we imagine will find no good reasons given here for abandoning the safe and simple method of saline injection." The other, in the *Lancet* in June 1918,²³ discussing "Transfusion of blood in military and civil practice," states "... we doubt whether any English surgeon could have been found to perform the operation of blood transfusion even so recently as 4 years ago." The only published response to this statement was a short

but indignant letter from Berkeley (later Lord Moynihan,²⁴ pointing out his awareness of Crile's work and listing the various methods he had used in performing transfusion in "many cases." However, Faulds,²⁵ writing in 1916, states "... I have never until the war broke out done 'direct transfusion of blood' for treatment of anything but collapse from hemorrhage and like many other surgeons can tell of numerous cases where it has been the means of saving the patient's life." No details were provided, but this would suggest that there were others besides Moynihan who were aware of the use of blood transfusion using the approach of Crile.

Britain thus entered the war with limited interest in, and knowledge and experience of, transfusion and without any organized preparation for transfusion support in the management of battlefield casualties.

Canada

The individual who effectively introduced blood transfusion to Canada was Lawrence Bruce Robertson.⁸ Bruce Robertson graduated in Medicine from the University of Toronto, Ontario, Canada, in 1909, and after a year as an intern at the Hospital for Sick Children in Toronto, Ontario, Canada, he spent 18 months in New York and, later, 6 months at the Children's Hospital Boston, Boston, Mass, for postgraduate training in surgery.

During his 18 months at Bellevue Hospital in New York, he worked with Lindeman, acquiring skills in the syringe technique of blood transfusion.⁴ It is highly likely that he would also acquire knowledge of other methods of transfusion such as those of Unger⁵ and the Kimpton-Brown tube,⁶ and of the newly emerging understanding of problems of blood group incompatibility. He returned to Toronto, taking up a staff appointment at the Hospital for Sick Children in 1913.²⁶ In the hospital's Annual Report for 1913 to 1914, transfusion appears for the first time in the list of surgical procedures. Robertson influenced both his surgical and medical colleagues in introducing them to the procedure that some adopted and used both before and after his departure for the war in Europe. With his medical colleague Alan Brown, in April 1915 just before his departure for Europe, he published a report of 27 children treated for various conditions with transfusion. In discussing these cases, they concluded that transfusion was "safe and not a complicated procedure," that danger from

hemolysis was overrated, and that, although transfusion had been immediately beneficial in all cases, the ultimate outcome depended on the original condition. The best results were in "hemorrhagic disease of the newborn, simple secondary anemia, and marasmus."²⁷ With his surgical colleague WE Gallie, he described the use of transfusion in 10 cases of surgical treatment of pyloric stenosis in infants between 1914 and 1916.²⁸ As will become evident later, he influenced the use of transfusion by others in the surgical disciplines at the Hospital. It appears that Bruce Robertson was the first Canadian to practice blood transfusion in any systematic manner.

In Montreal, Edward Archibald (later to become the Chairman of the Department of Surgery at McGill University and Surgeon-in-Chief at the Royal Victoria Hospital in Montreal) was also becoming aware of blood transfusion, and in December 1914, he visited Crile in Cleveland to learn more of his surgical procedure for transfusion.²⁹ Thus, another Canadian surgeon was prepared independently to use transfusion in the practice of surgery.

CANADIAN TRANSFUSION PRACTICES IN WORLD WAR I, 1914 TO 1918

Bruce Robertson enlisted in the Canadian Army Medical Corps (CAMC) at the outbreak of war in August 1914, remaining in Toronto until his unit was posted overseas in April 1915.³⁰ After several months in England, his unit, No. 2 Canadian Casualty Clearing Station, was sent to Aire in the Pas de Calais arriving on September 17, 1915. Because there was little work for the Canadian surgeons to do at this time and place, pending the establishment of their Casualty Clearing Station in its assigned location, Bruce Robertson was seconded to British medical units and to a British base hospital (No. 14 General Hospital near Boulogne) between October 5, 1915, and January 30, 1916, where he would be exposed to the British faith in saline for blood replacement, in contrast to his belief in the superior value of blood. During this period, he performed several transfusions. In April 1916 (14th to 22nd), he was granted leave^{9,30} to write his first article describing the use of transfusion in war surgery.³¹ In it, he describes 4 patients he transfused, for secondary hemorrhage after shrapnel wounds, between October 30, 1915, and January 17, 1916; one patient died of an apparent acute hemolytic reaction after a second transfusion.

(One of the patients was in the care of Major TR Elliot of the British Royal Army Medical Corps [RAMC] whose name will reappear in due course.) In this article, the first to address the topic of transfusion in war surgery in a major medical journal, Bruce Robertson describes various methods of transfusion in some detail (but does not mention citrate) and, although aware of the risks of hemolysis, regards it as “uncommon” and discounts testing in the light of the perceived urgency of treatment. The main thrust of the article was to urge the use of blood as the best replacement for the treatment of hemorrhage, describing saline as at best only a temporary measure. The language in which the article is written conveys a strong belief in the superiority of blood over saline as a resuscitative fluid in the management of blood loss, and it may be that his experience with the British preference for saline persuaded him of the need to urge for more energetic acceptance of blood transfusion in resuscitation.

Bruce Robertson returned to No. 2 Canadian Casualty Clearing Station (Fig 1) (by now, at Remy Siding in the Ypres sector, near Poperinghe, Belgium) in late January 1916 and served there until a secondment to the British No. 13 Stationary Hospital, British First Army, from August 1 to November 19, 1916. Although there is no published record of his use of transfusion during the period covered by these appointments, the secondment to the British Hospital certainly offered a further opportunity for him to demonstrate the use of transfusion to his British colleagues.

In November, he rejoined No. 2 Canadian Casualty Clearing Station (bed capacity, 300-



Fig 1. The medical and nursing officers of No. 2 Canadian Casualty Clearing Station, Poperinghe, 1917. Lawrence Bruce Robertson is seated at the right-hand end of the front row.³³

500³²) where he served until December 1917 when he was repatriated on health grounds. Casualty Clearing Stations (CCS) were generally several miles from the front at the apex of a “triangle of evacuation” from the front^{9,33} where triage, resuscitation, and emergency surgery were the main activities. Triage often involved decisions on separating those of the wounded with a reasonable hope of recovery from those believed to have no reasonable expectation of recovery and who were consigned to “the moribund ward.”³⁴

During his last year of service, a period covering the Third Battle of Ypres, and the Battles of Messines and Passchendaele, he continued his transfusion practices using both citrate and syringe and cannula techniques. In a set of 3 articles, he describes 68 cases with which he was involved and who were transfused during this period, 57 of primary and 9 of secondary hemorrhage, together with 2 cases of exchange transfusion for “carbon monoxide poisoning” with successful outcomes.^{35–37} Of the 57 cases of primary hemorrhage treated by transfusion, 36 were evacuated to base hospital in good condition, 15 died of other causes after temporary benefit, and 4 cases showed no benefit of transfusion. Of the 68 cases, 3 had hemolytic reactions, which were judged to have contributed to a fatal outcome. He advocated preliminary test injections of the blood to be transfused, under observation, for the prevention of acute hemolytic reactions.

Bruce Robertson returned to the Hospital for Sick Children in Toronto in 1918, resuming his surgical practice, including blood transfusions, which increased dramatically in number on his return.²⁶ Building on his experience with the 2 exchange transfusions he performed in Europe, he developed exchange transfusion for the management of the toxemia of burns in children,³⁸ supported by experimental evidence from animal studies.³⁹ He died of pneumonia after influenza in Toronto on February 24, 1923 (Fig 2).

Alexander Primrose and Stanley Ryerson were both colleagues of Bruce Robertson at the Toronto Hospital for Sick Children. They both enlisted on April 1, 1915, in the CAMC for overseas service with the Canadian Expeditionary Force as members of the medical staff of No. 4 Canadian General Hospital, sponsored by the University of Toronto. No. 4 hospital was assigned to Salonica in Greece in October 1915.^{40,41} In a report published in



Fig 2. Commemorative plaque to the memory of, and recognizing the achievements of, Lawrence Bruce Robertson in St Andrews Presbyterian Church, King and Simcoe Sts, Toronto.³³

September 1916⁴² of 2 soldiers treated with transfusion, one after having multiple fractures in a motor vehicle accident and another for management of postsurgical secondary hemorrhage, Primrose and Ryerson describe the “syringe and cannula method” “brought to our attention by Captain L. Bruce Robertson” who had “obtained the idea from one of the New York clinics.” They also discuss the value of transfusion in severe hemorrhage in military surgery, alluding to Bruce Robertson’s experience in Northern France.³¹ In a footnote, they state that this article was “Read before the Salonica Medical Society, April 5th 1916,” suggesting perhaps an attempt at establishing primacy of communication. Nevertheless, Robertson receives the credit for drawing their attention to the use of transfusion, and the publication of another article in a major British journal on transfusion under conditions of war could only serve to draw further attention to Bruce Robertson’s advocacy of blood transfusion in war surgery.

Yet, another of Bruce Robertson’s surgical colleagues used transfusion in treating the wounded, although he himself did not publish his experience. In his memoirs, Dr Norman Guiou (see below) noted that David E. Robertson, attached to the Third Field Ambulance Main Dressing Station at Albert, on the Somme, in the fall of 1916, gave a blood transfusion to a badly wounded man who survived.⁴³ He used a “citrate bottle ... sent to him by Dr Gallie of the Toronto General Hospital,”⁴³ providing a further link with transfusion in Toronto. It has been suggested⁹ that Guiou may have confused DE Robertson with Bruce Robertson, but the accuracy of his identification is confirmed by DE Robertson’s roll of service, which places him with Third Field Ambulance at the time in question.⁴⁴

Edward Archibald enlisted on April 7, 1915, and was posted to No. 3 Canadian General Hospital in France in June 1915, moving to No. 1 Casualty Clearing Station in December 1915 until late April 1916, returning to No. 3 Canadian General Hospital until his return to Canada in October 1916.⁴⁵ He reported on 4 transfusions in 3 patients treated by him and a colleague for secondary hemorrhage in the general hospital, and a further 5 who were transfused in the Casualty Clearing Station for primary hemorrhage^{46,47} using citrated blood, which he had learned from the work of Lewisohn.¹⁶ Of the 8, 6 died, 1 benefited and survived, and 1 survived despite having a suspected hemolytic reaction. In discussion, he points out that “only desperate cases have been chosen.” The main objective of his articles was not so much to advocate transfusion as to point out how the procedure could be simplified and hence made more readily available by the use of citrated blood. The earlier article was submitted in April 1916, the same month that Bruce Robertson was on leave to write his article. Archibald’s⁴⁶ article appeared 2 months after Bruce Robertson’s original article, and thus, he may have lost the opportunity for primacy of publication by his choice of journal. Beyond his publication of a fuller version of his experience in his second article in the *Journal of the RAMC*,⁴⁷ there is little or nothing to suggest that Archibald made any specific effort to promote blood transfusion by his British counterparts.

Dr Norman Guiou served in Europe as a medical student in the early years of the war, returning after graduation at McGill University to No. 3 Canadian General Hospital and various assignments to forward

units in 1917 to 1918.⁴⁸ In his memoirs,⁴³ he refers to the “first blood transfusion ... performed at the hospital” on October 27, 1915 (3 days before Bruce Robertson’s first reported transfusion).³¹ No details are provided, and there is no mention here (or anywhere else in the memoirs) of Archibald in connection with transfusion, nor, parenthetically, is there any mention of Bruce Robertson. In January 1918, he attended lectures on blood transfusion by 3 officers of the British RAMC and 1 from the CAMC.⁴³ This, together with his awareness of the advances in the use of citrated blood appropriately grouped,^{49,50} appears to have sparked his interest. He went on to establish the feasibility of transfusion at Advanced Dressing Stations in the Canadian Forces⁵¹ along with Walker in the British Third Army and Holmes a Court with the Australians.⁵² Guiou’s memoirs contain a set of 6 illustrations of paintings by Arthur Elias, depicting the care of the wounded including 2 of particular interest, bearing directly on conditions under which transfusions were carried out (Figs 3 and 4). These paintings used to be housed in the Medical Museum at McGill University under the supervision of Dr Maude Abbott. It appears that the paintings were taken by her to Washington,⁴³ but their current location is unknown.

TRANSFER OF TRANSFUSION KNOWLEDGE AND TECHNIQUE TO THE BRITISH

It is clear that Bruce Robertson’s experience with blood transfusion in New York had convinced him



Fig 3. Painting by AE Elias. Medical officer giving a transfusion at a Regimental Aid Post. The officer is using positive pressure to promote flow to the recipient. The same port could be used to apply negative pressure to enhance flow rates during donation. This was accepted practice, described in detail elsewhere.⁵⁹ This is one of 6 paintings illustrated in Guiou’s memoirs.⁴³ Reproduced with the kind permission of Stoneycroft Publishing, Yarmouth, Nova Scotia.

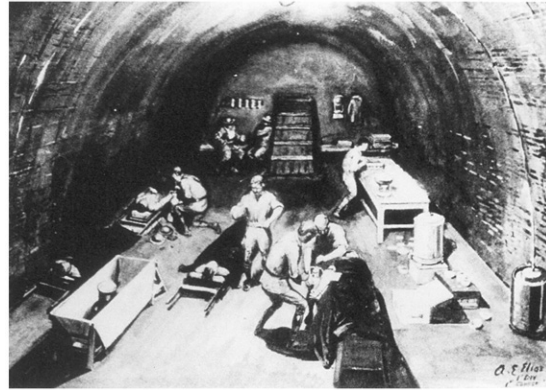


Fig 4. Painting by AE Elias. Interior view of a transfusion unit. At the back on the right, an NCO is reading an agglutination test. On the extreme left, a donor is being bled. Next to the donor, a patient has been lifted off a warming bed heated with an oil stove. On the right, a patient is being transfused.⁴³ Reproduced with the kind permission of Stoneycroft Publishing, Yarmouth, Nova Scotia.

of its therapeutic value. On his return to Toronto from New York, he introduced transfusion into the Hospital for Sick Children and quickly persuaded his medical and surgical colleagues to use transfusion in their clinical practice. Publications with Brown²⁷ and Gallie,²⁸ together with Primrose and Ryerson’s⁴² allusion to their source of knowledge of transfusion, attest to Bruce Robertson’s influence on his colleagues’ practice. On his arrival in France, much of his clinical activity was conducted in association with British surgical services where he would be aware of the British preference for saline as the resuscitative fluid of choice, and would, drawing on his experience in civilian practice, be convinced of the superiority of blood in this circumstance. He certainly wasted little time in introducing transfusion into practice; arriving at a British base hospital near Boulogne on October 5, 1915, he carried out his first reported transfusion on October 30.³¹ The tone of his first article in advocating strongly the use of blood for the management of acute hemorrhage also suggests impatience with the shortcomings of saline.³¹ One of the cases used to illustrate his preference for blood and referred to him by a British medical officer, TR Elliot, had a successful outcome. Elliot was the Medical Research Committee’s (MRC’s) liaison in France, concerned with the management of acute hemorrhage, and this base hospital was involved in the MRC’s research in resuscitation. A surgical unit was set aside for resuscitation of

patients with “wound shock,” and blood transfusion was in use in that unit by January 1917.⁹ The evidence for Bruce Robertson’s influence in promoting transfusion in this unit is circumstantial but nevertheless tenable.

More convincing is the opinion of Col CG Watson, a Consulting Surgeon with the British Army, commenting on the results of blood transfusion by Bruce Robertson and others—“Without doubt, transfusion of blood after primary hemorrhage is a life-saving device of the greatest value ...” and “For many years past, we have, in England at any rate, trusted to saline infusion to restore the balance after hemorrhage.” “The effects of blood transfusion are instantaneous and usually lasting; the effects of saline too often transitory—a flash in the pan—followed by greater collapse than before.”^{35,36} This comment illustrates the growing separation of opinion between the practicing surgeons in the field and the academic physiologists at home.^{3,53}

Once the No. 2 Canadian Casualty Clearing Station was established and Bruce Robertson returned to his unit, he was able to demonstrate the methods and benefits of transfusion to British surgeons from nearby CCSs, one observer noting after a transfusion “the change in the patient was most marked.”⁹ British visitors at various times included George Gask,⁹ Sir Cuthbert Wallace, and Sir Anthony Bowlby,³³ all senior and respected army surgeons. The Commanding Officer of No. 2 Canadian Casualty Clearing Station observed “the MO’s recently attached are very much interested in Maj Robertson’s transfusion of blood work and watched some demonstrations with keen interest.” His “work in this line has been most favorably reported upon by the Consultant Surgeons in the Army.”⁹

Surgeon General Sir George Makins, reviewing surgery at the front,⁵⁴ and citing Robertson³¹ and Archibald,⁴⁶ said of the management of hemorrhage “The main advance in treatment has consisted in a return to the practice of transfusion of ‘whole blood,’ which has in great measure displaced the unsatisfactory saline infusion. For the popularization of this method, we are mainly indebted to our Canadian colleagues in France.”

A publication of the RAMC in July 1915,⁵⁵ the “Memorandum on the treatment of injuries in war,” makes no mention of transfusion. An update published 2 1/2 years later⁵⁶ contains a short chapter on transfusion techniques and advocates its use in a variety of clinical circumstances.

A group of British surgeons, using a direct cannular method similar to Crile’s, reported on 16 patients with secondary hemorrhage treated with transfusion between July and October 1916,⁵⁷ citing the reports of Bruce Robertson,³¹ Archibald,⁴⁶ and Primrose and Ryerson.⁴² They also mentioned 3 additional cases treated by other British surgeons, 2 at a Casualty Clearing Station. They do not state where their 16 patients were treated. However, a history of the medical services in the Great War⁵² places them in the base hospital at Boulogne, the MRC’s principal site for resuscitation research and the same place where Bruce Robertson transfused the 4 patients reported in his earliest article. Thus, it is likely that they were directly or indirectly influenced by Bruce Robertson’s use of blood transfusion earlier in the same base hospital.

The same history, in reviewing blood transfusion,⁵² mentions Bruce Robertson and Archibald, and states that in 1916 and 1917, Canadian surgeons practiced and popularized the “indirect” method of blood transfusion. Walker observed that of cases temporarily resuscitated with “gum-infusion” in field ambulances, 70% required blood at the casualty clearing station.⁵² Gordon-Taylor, who assisted Bruce Robertson with his 2 cases treated with exchange transfusion and treated 2 others of his own, used transfusion in the management of 22 of a series of 75 cases of thoracoabdominal injuries with “relatively good results,” that is, some patients survived who would otherwise have died, and the survival rate of desperate cases was “trebled.”^{52,58}

In March 1918, a conference of allied surgeons took place in Paris, and one session was devoted to blood transfusion.⁵⁹ Delegates from the United States, Britain, Belgium, France, Italy, Japan, Portugal, and Serbia are listed, but none from Canada. Bruce Robertson was by then back in Canada, and his superior officer (identity unknown) for whom he had written an article for delivery at the conference had been recalled before the conference took place.³³ As a result, there was no Canadian contribution. Nevertheless, Bruce Robertson’s experience was cited in respect of adverse reactions and acceptable volumes of donations; he was one of the few authorities cited by name at that conference. The conference concluded, *inter alia*, that transfusion of blood was the treatment of choice for severe hemorrhage, that it was not of value in septic shock, and that secondary hemorrhage, coagulation disorders, and chronic anemia of

infection may constitute indications for transfusion. Thus, Bruce Robertson's advocacy of transfusion for hemorrhagic shock was vindicated by a conference of his peers.

Archibald's contributions had much less impact than Bruce Robertson's. Though recognized briefly in the Official History of the Great War⁵² and by Makins in his review,⁵⁴ and being the first to point out the value of citrated blood in simplifying the process of transfusion under war conditions, his work in this field has been largely ignored.²⁹ This may in part be a consequence of his shorter period of service—he returned to Canada in October 1916,⁴⁵ perhaps before the interest in blood transfusion had started to gain momentum. It is also possible that he lacked the energetic enthusiasm that characterized Bruce Robertson's advocacy of transfusion.

Primrose and Ryerson did no more than publicize and support Bruce Robertson's initiative. DE Robertson did not publish any account of his use of transfusion so we know nothing of what, if any, influence he had on his colleagues in the war.

Guiou came later to the use of transfusion, by which time, the use of citrated preserved blood had been developed and demonstrated by Oswald Robertson,⁵⁰ and the concept of the "universal donor"⁴⁹ was taking hold. Nevertheless, with his British, American, and Australian counterparts, he established the practice of transfusion at advanced dressing stations. It is worth noting that, in a curious twist of events, his interest in transfusion originated at least in part in his exposure to a series of lectures, some of which were delivered by British RAMC Officers.^{43,51}

DISCUSSION

That Canadian surgeons introduced blood transfusion in the management of war casualties in the British sector appears incontrovertible. There are multiple reasons why they were in a position to achieve this. First, the Europeans, and especially the British, had shown little interest in blood transfusion in the years leading up to the war and had largely disregarded the advances being made, and published, in the United States. Apart from an indeterminate, but small, number of surgeons, nobody was using blood transfusion. The scientific community, mainly physiologists, was preoccupied with saline, and later "gum solution," as the resuscitative fluid of choice.

Thus, there was essentially an intellectual and practical vacuum with regard to blood transfusion, with no established body of practical knowledge and experience.

Second, Canada in those days was the "Dominion of Canada" and very much more subject to policy decisions made in Britain than now. Furthermore, the population had much closer emotional ties and loyalties to the "Empire." As a result, it was inevitable that when war on Germany was declared by Britain on the violation of Belgium's territory, Canada's involvement would be immediate and enrollment to the armed services prompt and substantial.

Third, Canadian surgeons were geographically close to the US centers where work on transfusion was being undertaken, and they were in a position to acquire the knowledge and skills required. Both Bruce Robertson and Archibald availed themselves of the opportunity to learn about blood transfusion, the former as part of his surgical training for civilian practice before it was apparent there would be a war, the latter perhaps as part of his preparation for service. Thus, both were to a greater or lesser extent knowledgeable and technically competent. Bruce Robertson had strong views on the value of blood transfusion and was not afraid to advance his opinions.

Fourth, the United States, the repository of most of the knowledge and skills in blood transfusion, did not enter the war until April 1917, and hence, the war was almost 3 years old before those skills would be made directly available in Europe, with Oswald Robertson, trained in Boston and New York, bringing his up-to-date expertise in the use of preservatives, acquired at the Rockefeller Institute, and of blood grouping techniques.⁶⁰

As a result of this set of circumstances, the Canadians in small numbers had the knowledge and skills to use transfusion, acquired directly or indirectly from American sources. The British, with little or no ability in transfusion, and a preoccupation with crystalloid for resuscitation, had not developed a capacity for resuscitation with blood. The Canadians, especially Bruce Robertson, were therefore in a unique position, possessed of American expertise in an environment with no competition. It is greatly to their credit that they quite quickly, after their arrival in the war zones in Western Europe and Greece, were able to use

transfusion and, in the case of Bruce Robertson in particular, to start to persuade British Army surgeons of the superior efficacy of blood and teach them how to use it. It proved easier to “convert” the surgeons in the army by demonstrating “miracles” of recovery than to influence the scientists at home. Nevertheless, by war’s end, the value of prompt transfusion of blood in

resuscitation from hemorrhage in wounded soldiers had been generally accepted.^{54,59}

ACKNOWLEDGMENTS

I am indebted to Dr Kim Pelis for help in obtaining some of the less accessible references. Also, Elsa Benjamin and Josephine Canete provided valuable secretarial help.

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