

ORIGINAL ARTICLE

REDUCING TIME TO URGENT SURGERY BY TRANSPORTING RESOURCES TO THE TRAUMA PATIENT

MORGAN P. MCMONAGLE,*† ARTHAS FLABOURIS,*‡ MICHAEL J. A. PARR§ AND MICHAEL SUGRUE§

*NRMA CareFlight, NSW Medical Retrieval Service, †Department of Trauma Surgery, Westmead Hospital, §Liverpool Hospital, Sydney, New South Wales, and ‡Intensive Care Unit, Royal Adelaide Hospital, Adelaide, South Australia, Australia

Background: Time to definitive trauma care directly influences patient survival. Patient transport (retrieval) services are essential for the transportation of remotely located trauma patients to a major trauma centre. Trauma surgical expertise can potentially be combined with the usual retrieval response (surgically supported response) and delivered to the patient before patient transportation. We identified the frequency and circumstances of such surgically supported retrievals.

Methods: Retrospective review of trauma patients transported by the NRMA CareFlight, New South Wales Medical Retrieval Service, Australia, from 1999 to 2003, identifying patients who had a surgically supported retrieval response and an urgent surgical procedure carried out before patient transportation to a major trauma centre.

Results: Seven hundred and forty-nine trauma interhospital patient transfers were identified of which 511 (68%) were categorized as urgent and 64% of which were rural based. Three (0.4%) patients had a surgically supported retrieval response and had an urgent surgical procedure carried out before patient transportation. All patients benefited from that early surgical intervention.

Conclusion: A surgically supported retrieval response allows for the more timely delivery of urgent surgical care. Patients can potentially benefit from such a response. There are, however, important operational considerations in providing a surgically supported retrieval response.

Key words: definitive surgical care, emergency surgery, major trauma centre, retrieval service, retrieval team, surgically supported retrieval response.

Abbreviations: ICU, intensive care unit; MTC, major trauma centres; NSW, New South Wales; SBP, systolic blood pressure.

INTRODUCTION

Major trauma centres (MTC) have grown out of the need to improve the management of patients with severe injuries.¹ It is accepted that better patient outcomes are associated with dedicated trauma systems,^{2–6} shorter prehospital times^{5,7,8} and shorter times to definitive care^{9,10} after a severe injury.

Interhospital patient transport (retrieval) services developed from the need to transport seriously ill patients from hospitals lacking the resources to deliver definitive care, to hospitals with such resources. Critically ill patients undergoing retrieval require dedicated and appropriately skilled retrieval team members.^{11,12} Such skills are found amongst physicians from critical care backgrounds, such as anaesthesia, emergency medicine and intensive care and when combined with training in prehospital care and transport vehicle operational considerations, they make up the optimal out-of-hospital retrieval team.^{13–15}

Despite an optimal retrieval response, time taken to access definitive surgical care for a patient in a remote location can be

excessive.^{16,17} An alternative is to transport and deliver the necessary surgical resources to the patient's location before transporting the patient to an MTC.¹⁸ Theoretically this will reduce the time to definitive or urgent surgical care by a time period that is approximately equivalent to the sum of the time spent at the patient's location by the retrieval team and the time spent in transit to the MTC.

We sought to identify and describe the current frequency and the clinical and operational features of a combined critical care and surgical retrieval response to trauma patients who underwent a surgical procedure by the retrieval team before interhospital transport.

PATIENTS AND METHODS

All trauma interhospital retrievals between 1 January 1999 and 31 December 2003 conducted by the NRMA CareFlight, New South Wales (NSW) Medical Retrieval Service (Sydney, Australia) were identified through a database search. The medical records of patients for whom a time-critical surgical procedure was carried out before transport to the MTC, by a surgeon travelling as part of the retrieval team, were selected and reviewed. Patients who had only resuscitation procedures consistent with the early management of trauma (e.g. insertion of pleural drain, wound haemorrhage control and emergency surgical airway) were excluded.

M. P. McMonagle MB Bchir, MRCSI; A. Flabouris JFICM PostGrad AviatMed; M. J. A. Parr FANZCA FJFICM; M. Sugrue FRCSI FRACS.

Correspondence: Dr Arthas Flabouris, Intensive Care Unit, Royal Adelaide Hospital, North Terrace, Adelaide, SA 5000, Australia.
Email: aflabour@mail.rah.sa.gov.au

Accepted for publication 29 October 2006.

In NSW, individual hospitals do not conduct interhospital transportation of critically ill patients of their own accord, but rather it is systematically organized through a central retrieval unit, which tasks stand-alone specialist retrieval services.¹⁹ The NRMA CareFlight, one of the retrieval services, has retrieval teams available for immediate response consisting of a paramedical ambulance officer and doctor using road, fixed-wing and helicopter vehicles. The doctors are either specialists or senior trainees from anaesthesia, emergency medicine or intensive care. Trainees from other specialities (e.g. surgery) or with prior trauma surgical training are uncommon and are required to have extensive experience in a critical care area before deployment. Typically, surgical advice and/or support could be sought through phone contacts with individual surgeons, if available at the time of request. The availability of a surgeon would be dependent on their usual hospital responsibilities, with no guarantee of availability for retrieval.

RESULTS

There were 4124 interhospital patient transfers over the 5-year period of which 749 (18.2%) were trauma related. Of these 230 (31%) were categorized as requiring an immediate retrieval response, 281 (37.5%) as an urgent (less than 60 min) response and 479 (64%) were from a rural hospital. Table 1 lists the demographic data of the immediate and urgent interhospital trauma transfers.

Three (0.4%) cases involved a surgeon as part of the retrieval response who could also carry out an urgent surgical procedure before patient transport. We describe these cases.

Table 1. Demographic and transport data for the 511 urgent trauma interhospital transfer patients

Age	38.7 (\pm 21) years
Men (%)	75
Invasive positive pressure ventilation (%)	70.7
Trauma patients transported from a rural hospital (%)	63.8
Mode of transportation (%)	
Helicopter	68
Road	25.2
Fixed wing	6.7
Mean time retrieval team leave the base (24 hour clock)	13:41 (\pm 6:52) hours
Retrieval response time (from departure of base to arrival at referring hospital) (min)	48 (\pm 39)
Time from base to patient arrival at MTC (min)	148 (\pm 100)
Potential time 'saved' to first surgical review (if surgeon included as part of the immediate retrieval response) (min) [†]	102 (\pm 67)
Category of trauma (%)	
Head injury	37
Multitrauma	35
Burns (including airway)	12.1
Spinal injury	7.4
Thoracic injury	3.1
Airway injury	1.1

[†]Mean potential time saved is the mean value of the difference between the time from base to patient arrival at MTC and retrieval response time. MTC, major trauma centre.

Case 1

At 16:20 hours the ambulance service attended to a 36-year-old woman with a self-inflicted stab wound in the 4th intercostal space to the left of the sternum. At the scene she was conscious, pale, diaphoretic and had an unrecordable blood pressure. The electrocardiogram rhythm strip showed a sinus rhythm at 100 b.p.m. Attempts at prehospital intravenous cannulation by the ambulance personnel were unsuccessful.

At 16:53 hours they left the scene for the nearest hospital, a regional hospital that was approximately 15 min closer by road, but in a direction away from the nearest MTC, arriving there at 17:00 hours. On arrival, the systolic blood pressure (SBP) was 114 mmHg and the pulse 84 b.p.m. The trauma team responded promptly and included trainee doctors from surgery, anaesthesia and emergency medicine.

Approximately 30 min later the SBP fell to 50 mmHg, the pulse rate to 50 b.p.m. and the patient became unrousable. Then an oral endotracheal tube and a left-sided intercostal drain were inserted. The patient had received 3.5 L of intravenous colloid and it was noted that the neck veins were now distended. These clinical findings along with persistent hypotension led to a presumptive diagnosis of cardiac tamponade.

As there was no on-site surgical expertise capable of managing this condition, an urgent request for an immediate retrieval of the patient was made to the MTC trauma hotline at 17:24 hours.²⁰ Following discussion with the on-call MTC trauma surgeon, the decision was made to bring the necessary surgical expertise to the patient's location. The trauma surgeon activated the retrieval service through a dedicated retrieval phone number.

The retrieval team, consisting of a doctor (consultant anaesthetist), paramedical ambulance officer and two flight crew, were tasked by helicopter (Bell 412), first to the MTC for the trauma surgeon, who brought no extra surgical equipment or personnel, and then to the regional hospital, arriving at 18:10 hours. The patient was transferred to the operating theatre at 18:20 hours and surgery commenced at 18:28 hours. By this time the patient had received a further three units of blood and had been commenced on an adrenaline infusion.

An anterolateral thoracotomy was carried out, showing a tight, bulging haemopericardium. The pericardial sac was opened by a vertical incision and a large blood clot was evacuated. There was a 1 cm full-thickness laceration in the anterior wall of the right ventricle, which was sutured. The pericardium was drained and closed and further drains were placed in the mediastinum and the left pleural cavity, before closing the chest.

The patient's condition improved allowing the adrenaline infusion to be discontinued. The patient was kept sedated, ventilated and prepared for transfer to the MTC, leaving at 21:30 hours and arriving at 22:00 hours. In-flight monitoring included that of electrocardiography, invasive blood pressure, pulse oximetry and capnography. The patient was extubated and discharged from the intensive care unit (ICU) the following day and from the hospital 7 days later after an uneventful recovery.

Case 2

At 20:50 hours ambulance officers attended to a 19-year-old man with an abdominal stab wound. At the scene, the patient was conscious with a SBP of 130 mmHg and a pulse rate of 84 b.p.m. At 20:59 hours the ambulance left with the patient for the nearest hospital, a rural hospital 100 km from the nearest MTC, arriving at 21:27 hours. Examination by the emergency

department doctor showed a stable patient with a single stab wound to the left lower quadrant with protrusion of abdominal viscera. Approximately 30 min later, the SBP dropped to 98 mmHg. An intravenous bolus of 500 mL of colloid and 500 mL of crystalloid were given. The local general surgeon was contacted who decided to proceed to an emergency laparotomy, commencing at 00:04 hours. A specialist anaesthetist conducted the anaesthesia.

Laparotomy findings included a lacerated sigmoid mesentery, a small splenic laceration (not actively bleeding) and a large expanding retroperitoneal haematoma. The surgeon was not adequately experienced in the management of retroperitoneal injuries and at 00:50 hours sought advice from the on-call trauma surgeon at the MTC using the trauma hotline.²⁰ The patient had received a further 1000 mL of intravenous colloid fluid and two units of O-negative blood.

Because of the potential seriousness of the injury, failure of adequate haemorrhage control and the patient's ongoing need for intravenous fluid, the MTC trauma surgeon decided to attend and assist with the operation at the rural hospital. The CareFlight retrieval team, consisting of a doctor (senior emergency medicine trainee), a paramedical ambulance officer and two flight crew left their base by helicopter (Bell 412) at 01:14 hours, collecting the MTC trauma surgeon en route, who elected not to take additional equipment or personnel, arriving at the rural hospital at 02:20 hours.

At surgery, the trauma surgeon gained haemorrhage control by first carrying out a medial visceral rotation with arterial inflow and outflow control.²¹ The retroperitoneal haematoma was opened and evacuated, showing a deep laceration to the left psoas muscle. Haemostasis was established and the abdomen lavaged and closed at 03:40 hours. The patient had received a further four units of O-negative blood, two units of fresh-frozen plasma and 2000 mL of crystalloid intravenous fluids.

The patient's condition was stable at the completion of surgery. He was kept sedated, ventilated and prepared for transport to the MTC, leaving the rural hospital at 04:18 hours and arriving at 04:45 hours. In-flight monitoring included that of electrocardiography, invasive blood pressure, capnography and pulse oximetry. The patient was extubated and discharged from the ICU the following day and from the hospital 7 days later following an uneventful recovery.

Case 3

At 05:00 hours a 16-year-old man sustained 70% full-thickness, circumferential burns to the arms, head, neck, chest and abdomen in a small rural town, 1500 km from the nearest MTC. The attending ambulance officers felt that the overwhelming nature of the injuries exceeded the capabilities of the town's rural medical centre (staffed by a sole general practitioner), and according to ambulance service protocol, requested for an urgent retrieval team response through ambulance radio communications. At 06:30 hours the retrieval team, consisting of a CareFlight doctor and paramedic along with a flight nurse from the Royal Flying Doctor Service of Australia, left by a fixed-wing aircraft (Beechcraft King Air 200C) for the rural town, arriving at 11:00 hours. On this occasion the retrieval doctor was a senior surgical trainee with prior critical care experience.

The local doctor had carried out endotracheal intubation and had initiated mechanical ventilation and fluid resuscitation. At the arrival of the retrieval team the patient was oliguric with an SBP of 80 mmHg. The upper-limb peripheries were tense and cold, without a palpable pulse and the peak airway pressure was greater

than 40 cmH₂O. The need for urgent extensive escharotomies was not clear at the time of dispatch of the retrieval team from the initial information provided.

The retrieval doctor made the decision to carry out urgent escharotomies in the medical centre operating theatre, where normally only minor surgical procedures are undertaken. The rural practitioner, who had anaesthetic experience, managed the anaesthesia and the rural nursing staff assisted with the surgery. Extensive escharotomies were carried out to upper limbs, chest and abdomen, using diathermy to achieve haemostasis. The wounds were dressed with petroleum jelly gauze and cotton bandages. The patient received four units of blood during the procedure. The peak airway pressure fell to the vicinity of 30 cmH₂O following the surgical procedure.

At 15:00 hours the retrieval team left with the patient, arriving at the MTC at 17:30 hours, more than 12 hours after the initial injury. During transport the patient was kept sedated, ventilated and received intravenous fluid resuscitation. In-flight monitoring included that of electrocardiography, invasive blood pressure, capnography, pulse oximetry and urine output. The patient spent 6 weeks in the ICU, underwent further wound debridement and skin grafting, but with preservation of all limbs. He was discharged home 4 months later.

DISCUSSION

We describe three patients for whom surgical expertise was integrated as part of the usual retrieval response and delivered to the patient at the referring hospital, before transport to an MTC. Although this occurred infrequently, the cases described showed considerable patient benefit.

Trauma is considered a surgical disease and historically trauma care has been led by general surgeons.²² This premise is based on the fact that urgent haemostasis and definitive trauma care often requires general surgical skills.^{3,22} The current practice of trauma care is multidisciplinary, involving critical care-based specialities, interventional radiology and various surgical subspecialties (cardiothoracic surgery, neurosurgery etc.).^{23,24}

Trauma care in the rural setting occurs remote from an MTC and is delivered by medical staff with far less experience and insufficient training in the care of critically ill trauma patients.²⁵⁻²⁷ Rural hospitals are reported to have higher rates of morbidity and mortality for trauma in comparison to MTC^{6,28,29} and when combined they call on closer links between MTC and rural hospitals.^{28,29} Such links may include interhospital transfer guidelines,³⁰ timely consultation capabilities, referral and retrieval.²⁰ An MTC linked to a dedicated retrieval service has been associated with improved patient outcomes.^{13,31}

It has been suggested that trauma surgeons participate in pre-hospital care.^{32,33} However, the necessary prehospital care skills are those of advanced life support, such as airway, mechanical ventilation and i.v. fluid management, skills that are more familiar and practised by 'critical care' trained doctors.³³ In comparison, for interhospital patient transports, the benefits of a trauma surgeon as part of the retrieval response, delivering surgical care to the patient at remote medical facilities, is not well documented or debated. The patients described with surgically supported retrievals account for only three (0.4% of total or 0.6% of urgent trauma transfers) patients of a total of 749 trauma transfers over a 5-year period. Gilligan *et al.* recorded 48 (4%) trauma patient transfers from a total of 1169 trauma patients over a 12-year

period, who had surgery at the referring hospital before transfer.¹⁸ A surgeon (neurosurgeon) from the MTC accompanied the retrieval team (but did not necessarily carry out surgery) for 16 (1.4%) of these missions.

There are significant resource considerations for the provision of surgically supported retrievals. These considerations would need to be balanced with any potential benefit to the patient and risk of delaying definitive treatment and transportation of the patient to the MTC. Ideally the surgeon should be of a senior level, based within MTC and be capable of providing definitive surgical care across a range of surgical subspecialties within environments lacking the typical MTC-level surgical infrastructure and support (e.g. laboratory and blood product support, preferred surgical instruments, usual operating theatre staff and postoperative facilities). They would be required to be available for immediate tasking for retrieval without disruption to the usual MTC surgical services. The surgeon would also be reliant on and work together with transport vehicle pilots and crew as well as the retrieval critical care specialists who would provide support during the preoperative, intraoperative and postoperative periods. This support could be incorporated and delivered from within the usual retrieval team (case 1), include referring hospital staff (case 2) or a combination of the two (case 3) and would require extensive prior planning and preparation as well as training of selected personnel beyond current surgical and retrieval practice. In addition, such a system has the potential advantage of providing a central coordination point of care for the trauma patient that includes surgical advice, requests for the usual retrieval response, accompanying surgical resources and reception at the MTC. Surgeons, if part of the retrieval team, would require additional training in operational retrieval procedures, such as familiarization with transport vehicle operations, safety, on-board communication equipment and procedures, transport medical monitoring and provision of appropriate clothing, helmets and other personal protective equipment.

The transport environment would need to be able to safely accommodate the stowage of surgical equipment and dangerous goods, such as blood products. For example, aircraft configuration has limited space and weight capacity. For two of the patients we describe, the mode of transportation was a Bell 412 helicopter, which is one of the larger capacity (cabin volume 6.23 m³) civilian medical retrieval helicopters currently in use in Australia. In contrast, a floor space of 20 m² is recommended for an adult ICU bedspace.³⁴ Smaller aircraft that are currently in use, such as the Eurocopter BK117 (cabin volume 5 m³), Augusta AK109 (cabin volume 5.1 m³), Dauphine AS 365 N3 (cabin volume 5 m³) are less likely to accommodate the standard retrieval crew, their equipment, a patient on a stretcher, a surgeon, surgical equipment and potentially additional surgical assistants. Surgical equipment would also need to be versatile in design and packaging to fit safely and securely across a range of transport vehicles and aircraft. Finally, additional weight can increase an aircraft's fuel consumption and limit its range and the height it can fly. The mean time of day of request for interhospital trauma patient referral was 13:40 hours. The average mission duration (time from tasking retrieval team to patient arrival at the receiving hospital) was 2.5 h. The latter does not include additional surgical procedural 'time'. This would be a significant allocation of surgical resources from the MTC, at a busy time of the day. In our environment, the time 'saved' in delivering urgent trauma surgical expertise to the patient (assuming there is a surgical team rostered for immediate dispatch and the retrieval response is not otherwise

delayed) is at best, an average of 102 min. This value reflects the time the retrieval team would have spent at the referring hospital and then the patient transport time to the MTC and it assumes any surgically supported retrieval response would, on arrival at the referring hospital, be direct to the operating theatre, as that occurred for cases 1 and 2.

Cases 1 and 2 also illustrate the importance of a single point of referral (the trauma hotline) for timely communication with an MTC trauma surgeon and the opportunity to differentiate the need for urgent surgical support with the retrieval compared with a standard retrieval response.²⁰ Potential disadvantages of a single point of referral is that it involves a decision by the user of which number to call first (i.e. trauma or retrieval hotline) and this may depend on how busy and possibly how inexperienced the referring clinicians are as well as the experience of the call receivers to be able to exchange the desired information and reach the best solution for the prevailing clinical problem. For example, in case 3, it may have been possible to guide the rural doctor, depending on their clinical expertise, through the escharotomy procedure. Facilities, such as videoconferencing, not available at the time, can enhance the exchange of communication and better guide such therapy in a remote location.

Trauma bypass policies are designed to reduce the time to an MTC by avoiding delays associated with secondary transfer from a non-MTC. However, such policies on trauma bypass are not always followed (case 1) or are not feasible for more distant and rural hospitals (cases 2 and 3).³⁵ Case 3 illustrates that early, prehospital notification and activation of the retrieval service is still possible and beneficial despite the great distances involved. It could be argued that the patients in cases 1 and 2 could have been transported to the MTC rather than transporting the surgeon to the patient. Such decisions to transport or 'stay and treat' trauma patients at a rural hospital, with ongoing life-threatening cardiovascular instability must be made after considering the risk of transport with inexperienced or non-critical care trained physician escorts with limited resources compared with the risks of maintaining advanced resuscitation while awaiting definitive surgical treatment.

In our study, most of the trauma patients were referred from a rural hospital. Rural-based surgeons can be trained to deliver both definitive and emergency surgery and to have these skills maintained.³⁶⁻³⁸ This could reduce the need for surgically supported retrievals as well as improve the mortality and morbidity associated with trauma management outside a MTC. For example, most of the trauma patients described by Gilligan *et al.* who underwent surgery before transport, were operated on by a member of the referring hospital surgical team.¹⁸ Current and future advances in telemedicine, simulation-based education and robotics could also influence the occurrence of combined surgical/critical care retrieval.

Our study of combined surgically supported retrievals is limited to the experiences of just one retrieval service. This study, along with the only other similar and Australian-based study suggests that the need for a surgically supported retrieval is infrequent and varies among different geographical regions.¹⁸ We could not provide a measure of the number of cases for which a surgically supported retrieval may have been beneficial but was not used. For example, 37% (152) of patients in our study had an isolated head injury, yet no neurosurgeon was used as compared with the findings by Gilligan *et al.*¹⁸ Other regional retrieval services within Australia with a larger proportion of rural interhospital transfers and over longer distances may have an even

greater proportion of patients for which a surgically supported retrieval service is required.

Two of the three patients in the study involved penetrating injuries. In 2003, in NSW, of patients admitted to a MTC with an injury severity score > 15, 69 (3% of all patients) were stabbed or shot, 623 (29%) were transferred from another hospital, 209 (10% of all patients) were retrieved by helicopter and 71 (3.4% of all patients) by fixed-wing aircraft.³⁹ It is important that an MTC should consider their own unique trauma distribution, referral pattern, retrieval operational capabilities along with the potential need for a surgically supported retrieval and balance it with their resource capacity to provide such a response. Identification of missed opportunities to provide a potentially beneficial surgically supported response should be considered as a quality measure for each major trauma service.

In conclusion we have described three patients who benefited from the timely delivery of a surgically supported retrieval response. Based on measures of current practice, such occurrences are infrequent, but the benefit to the patient can be significant. We recommend that all MTC and retrieval services further evaluate their capacity and need for (if any), of a surgically supported retrieval response within their region. An audit of missed opportunities for such a response should be considered as a quality measure of trauma service provision.

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