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Inter-hospital transport systems for the critically ill

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Abstract. Inter-hospital Patient Transport Services (IHPTS) are a unique collaboration between clinical and aviation/operational transport systems. The utilisation of such services is driven by regional health, the need to maintain equity of specialty medical service delivery and geographic factors. Both such factors change with time, and IHPTS must keep abreast of such changes. Assessment of earlier patient transports have identified the clinical and process benefit in terms of patient morbidity and mortality, and transport resource efficiency for specialty transport services. For any inter-hospital patient transport system, dedicated and efficient communication links between referral, transport and receiving facility reception is vital. When more competing tasks occur, a centralised tasking organization becomes necessary. IHPTS may be hospital based or by independent providers. The former have the advantage of close affiliation with specialised hospital based resources whilst the latter function without competing for scarce in hospital resources. The clinical component of the IHPTS can benefit by a strong interaction with the aviation/operational component. This diversity of knowledge in terms of skill, non-clinical expertise and quality processes that results, as well as the increased complexity of patients and their case mix has seen IHPTS evolve into a unique, specialised, field of medicine. The best utilisation of such services (in terms of vehicle and clinical crew selection), the risk benefit of complex critically ill patients, equipment use and choice and the transport environment remains to be validated.

Introduction

All nations face a variety of challenges in terms of maintaining equitable access of medical services for their population. These challenges are related to geography, population distribution, regionalization of specialty medical services, vehicular access, service facilities at remote communities, communication technology and occurrence of variations with time. For example, in 1996, 13% of the Australian population lived in rural areas as compared to 43% in 1911. Their impact is not insignificant. Regionalisation of specialty services can be of potential benefit for a diverse group of services such as adult and paediatric Intensive Care [1-3], trauma [4, 5] and stroke [6]. In contrast to those benefits, the rate of rural trauma deaths is greater than for urban [7-9], time to discovery of the injured is longer, medical staffing and level of training is lesser as is clinical exposure for local medical staff to patients with a higher severity of illness [10].

Inter-hospital Patient Transport Services (IHPTS) arose, and matured on, the basis of a nationwide equity for timely access to specialty health services and trends in health resource distribution. The aim was to deliver medical services to remote locations and/or deliver the patient to the regional medical services. An early example of a "flying doctor" comes from New Zealand, in 1922, where pilot, George Bolt, flew Doctor, W.A. Fairclough, an ophthalmic surgeon, from Auckland to Tauranga, a distance of 150 Kms, to perform an operation. On that same day, George Bolt demonstrated what was to be the future commercial reality for aeromedical service provision. He provided to the public joy flights whilst awaiting the time of completion of surgery and departure of the doctor [11]. The first worldwide example of a dedicated civil type service was the Royal Flying Doctor Service of Australia, founded by John Flynn and Clifford Peel in 1928. They demonstrated the importance of an extensive medical consultative communication network linking remote and centralised facilities by radio and telephone. The service was described by the Australian Prime Minister at that time as the "greatest single contribution to the effective settlement of the far distant back country that we have witnessed in our time".

The first dedicated critical care patient transport teams, were seen in the early 1970s. Taylor and colleagues in 1970 [12] describe the use of a modified hospital trolley with monitoring and resuscitation equipment for intra-hospital transport of cardiac patients in Boston. The Shock Team from the Western Infirmary, Glasgow [13] was established around this time, the Royal Adelaide Hospital Retrieval Service [14] dates from 1974 and Stanford University's Adult Transport Team [15] from the late 1970s.

Early inter-hospital patient transfer documented inadequacies of patient care, associated morbidity [16-20], observed mortality in excess of expected and higher mortality as compared to similar patients who were not transferred [21,22]. Major physiological disturbances such as hypoxia, hypotension, missed injuries, intravenous access, airway, ventilation, spine and limb immobilisation and communication problems were most often documented. Unresolved physiological instability at the referral site, and lack of transport experience by the escorting team, where predictive of in transit adverse patient events [23,24]. These basic errors clearly illustrated the necessity for guidelines for safe practice during transport [25-28] and for staff of appropriate clinical experience and skill mix for improved patient outcome [29,30]. Critically ill patients in need of interhospital transport have an average severity of illness that is greater than that of the general Intensive Care Unit [ICU] patient population [22,31,32]. As a result IHPTS have gone on to developed the clinical, logistical and transport expertise to provide an increasingly complex in transit delivery of critical care [33,34].

Hospital based Inter-hospital Patient Transport Services

Hospital based IHPTS [14,35,36] source their personnel from their own hospital medical and nursing pool. They may be dedicated staff rostered, or on call, for such duties or relocate staff from other duties. Such services have the advantage of taking early control and command of referrals for inter-hospital

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patient transportation. This allows for forward planning and resource allocation for patient reception, optimal patient preparation by the referring staff, under guidance of staff associated with patient specific medical specialty services, and pre departure planning by the transporting team.

The extent of consumption of existing hospital-based resources for such a transport service is dependent upon referral base size, complexity and exclusivity of specialty services at the referral hospital. Hospital based IHPTS services need not be restricted to large urban-based tertiary referral centres, but can be made available from regional rural hospitals [37]. These services may be limited in their capacity to spare on duty staff without restricting other hospital services. This is especially so in the provision of senior nursing and medical staff for transport duties.

Advantages of hospital based IHPTS are deployment of staff who often may work together during transport and their usual hospital environment. This fosters a strong team ethos through familiarity in clinical practice, procedures and equipment. Awareness of their own hospital unique circumstances, allows for efficient access to in hospital resources, such as specialty medical consultation, equipment replacement and sterilisation and uncommon and/or expensive drugs (eg antivenom, antidotes, blood products, etc). Such resources can then be mobilised and delivered, together with the transport platform directly to the patients at the referral site [38,39]. Finally often used disposable equipment compatibility, eg pressure transducers, drug infusion systems and portals reduces can be retained at the receiving hospital, thus reducing wastage and exposure of patient to otherwise unnecessary repetition of procedures. Such repetition includes routine blood, radiological and other investigations performed and interpreted at the referring site [40].

Most IHPTS utilise transport vehicles supplied by aviation [14] or land based commercial transport services (eg local ambulance vehicles) [14]. Ideally vehicles should be dedicated to a patient transportation role. Economic and operational realities however result in such vehicles to be utilised for other commercial purposes when not in patient transport mode. This can delay deployment of IHPTS, but in circumstances of infrequent use it does allows a means for their economical viability and an opportunity for the pilots/drivers to retain their currency. Vehicles may be based at the hospital or other nearby site. For tertiary referral sites with a high and/or time critical referral load, a secured hospital reception site, staff, ground loading bay and a helipad must be available and serviceable. An agreed process for the timely

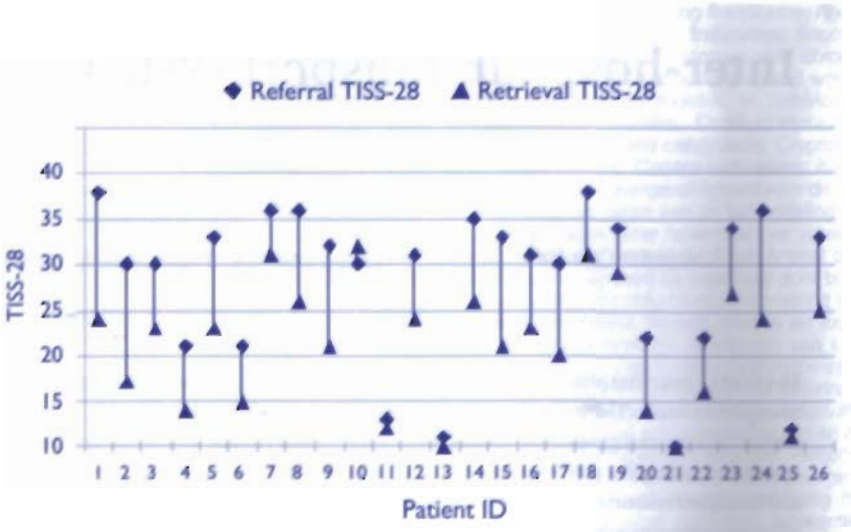

Figure 1. Illustrates the difference in transport TISS-28 from Referral TISS-28. Overall mean reduction was 24.5 +/- 12.5%.

deployment and reception of vehicle and non-medical personnel must be established. Hospital staff must be familiar with on board procedures and equipment for all types of vehicles they would be expected to travel in, including communication devices and those to do with safety.

Non-Hospital based Inter-hospital Patient Transport Services

Non-hospital based IHPTS are administratively independent, and supply the medical and aviation crew for the predominate purpose of inter-facility patient transfer. Their operational focus is solely upon safe out of hospital patient transportation [41] and distant from competing in hospital competing. Expertise is accumulated at a faster rate through the concentration of tasking, use of dedicated vehicles, staff and equipment resources. The higher volume of clinical and aviation transport exposure also positively contributes to crew performance [42] and patient safety [43]. Staff are rostered solely for such tasks and not removed from an existing and depleted hospital staff pool with resultant disruption to usual hospital services [44]. Equally important is for such services whose workload is not considered sufficient that clinical, operational and aviation skills are maintained. For medical/nursing/paramedical staff, this may be through intermittent rotations to tertiary referral hospitals.

It would be desirable for non hospital IHPTS to have arrangements with tertiary referral hospitals for access to speciality medical and surgical services consultation, utilisation of hospital services such as equipment sterilisation, pharmacy and blood products as well as in hospital educational and audit activities pertaining to the transport service activities.

Finally, non-government transport services should work closely with local and national government for the possible provision of transport services during extra ordinary circumstances such as disasters and major medical incidents.

The financial burden of IHPTS is often borne by government alone or in combination with private enterprise. In Australia and New Zealand the latter include major contributions from charitable organization, financial and insurance institutions, sporting and recreational associations and through public donation.

IHPTS accreditation and oversight

Accreditation and monitoring of independent IHPTS provision, including organisational safety, quality and training currency should be independently monitored. This should include hospital based IHPTS teams, which may be less likely to maintain pre determined standards and less enthusiastic to run and bear the cost of such services [44], especially in densely populated regions where the distance between tertiary referral centres less and the overall influence of a transport service is less. For both hospital and non-hospital based IHPTS which are independent to the aviation/transport vehicle service, a shared relationship which ensures conjoint participation in training and quality activities between the two is vital.

When there is more than one IHPTS, operational bases, or tasking agency, then co ordination of response through centralised tasking via a single dedicated line of

communication becomes essential. This would allow for prioritisation of requests and for establishing communication links between referring, transporting and receiving staff. It will also allow for an equitable distribution of referred patients amongst IHPTS and receiving sites

Figure 2. The 5 "R"s of patient transportation

Medical Crew - Crew Selection, Accreditation and Training

Studies of events during inter-hospital transfers of critically ill patients from the 1980s have documented inadequacies of patient care and significant associated morbidity [16-20] and an observed mortality in excess of expected mortality when compared to similar non-transferred patients [21,22]. Patients admitted to a tertiary referral ICU following transfer from another hospital have higher severity of illness measures than non transferred admissions [22,31]. In recognition of these events standards for the safe conduct of out of hospital patient transportation have been developed [25-28].

Of in transit events, major physiological disturbances such as hypoxia, hypotension, missed injuries, intravenous access, airway, ventilation, spine and limb immobilisation and communication problems are the most often described. Unresolved physiological instability at the referral site, and lack of transport experience by the escorting team, are predictive of in transit adverse patient events [23,24]. It is therefore essential that the escorting medical team have the skills for monitoring, recognising and managing acute physiological disturbances associated with a broad range of patient illness, rather than staff with medical expertise limited to specific disease categories.

Referrals arising from remote community hospitals with limited resources, staffed by solely nurse practitioners or medical staff who infrequently encounter critically ill patients, provide a greater challenge. In those situations transporting staff must be capable of providing a level of expertise and equipment that supplements that available at the referral site and meets the patient's immediate care requirements.

Circumstances associated with inter-hospital patient transport are thus highly varied. Transporting staff must not only possess the clinical skills but also have the seniority and clinical maturity to work unsupervised and adapt their clinical practices for the unpredictable circumstances that may be presented to them.

Older studies have documented major interventions, or the need for such interventions, by transporting medical staff upon arrival at the referring site [45,46]. A recent study, using TISS-28, as a measure for therapeutic intervention, showed the level of intervention in transit was equal to or less than that provided for at the referral site (figure 1) [47]. At time of transporting staff arrival at the referral site, all patients in need airway protection and/or respiratory support had been intubated and were receiving mechanical ventilatory support and all those with cardiovascular instability were receiving intravenous fluids and/or inotropes. The transporting medical staff did however identify undetected errors of airway/ventilatory management in 33% of patients receiving mechanical ventilation. Such data would indicate that based upon current practice, the role of transporting medical staff is shifting from providing basic major interventions (eg oral intubation, central vascular accesses, initiation of inotrope, etc) to that of providing a higher level of clinical judgement or more specialised expertise.

Sound and well-practiced communication skills are vital for transporting medical teams. These skills include a familiarity with the use of a range of communication aids and an ability to seek and express relevant clinical information in a clear, determined and timely format to a range of clinicians and non-clinical personnel.

The potentially unpredictable transport environment is more stressful for the inexperienced escort than unfamiliar hospital environments. Escorts rely upon a greater degree of situational awareness often associated with a more intense and prolonged clinical workload. Within this environment successful team function depends upon effective interaction amongst team members, of which familiarity, communication, effective leadership and team cultural factors play a part [48].

Medical staff should be selected based upon extensive in hospital critical care experience, a demonstrated ability to function unsupervised, communication and leadership skills, and the ability to work within a variety of team structures. Training should incorporate medical and personal protective equipment as well as vehicle familiarisation, especially the associated safety/emergency procedures. The latter include vehicle emergency and safety features, (eg where applicable, helicopter underwater escape training, hypoxia awareness training), and clinical performance within the constraints of such vehicles.

Currently there is wealth of information about the aviation environment and it's impact upon healthy aviators. There is much less information as to the clinical consequences

Table 1. Advantages and disadvantages for the commonly utilised interhospital modes of patient transportation

ROTOR WING AIRCRAFT	Advantages	Rapid activation time, "door to door" operations, all weather capability, capabilities and limitations well understood by referring staff, patient loading easier, drivers require less training, weight and space not as crucial, easy to re stock in transit, ambulance bays more common
	Disadvantages	Slow speed, acceleration and deceleration forces easily transmitted to patient, crew and equipment, low frequency, high amplitude vibration (jolts), influenced by terrain, limited to shorter distances, slow response time if specialist team travels from afar.
FIXED WING AIRCRAFT	Advantages	Speed (typically 120 – 150 knots, 240 – 300 kph), "door to door" capability depending on available landing zones
	Disadvantages	Activation time (3 to 15 minutes depending on program), noise, high frequency, low amplitude vibration, limited access to patient in transit, restricted by weather conditions, instrument flight capabilities, weight restrictions, patient loading difficulties, high level of pilot training and medical crew familiarisation
	Advantages	Speed (250 – 500 knots, 500 – 1000 kph or more), cabin space and comfort, cabin sea level pressurisation in some aircraft, ability to operate in weather conditions which preclude helicopter operations, fewer weight restrictions, longer range.
	Disadvantages	Activation time longer, limited to operations from airfields, with mandatory road trips at either end, patient loading difficulties, high level of pilot training

and significance of effects at the critically ill patient – transport environment interface. Most assumptions as to the patient risk/benefit within this environment are derived from our existing knowledge of pathophysiology, medical equipment operations and environmental characteristics. Therefore not only is a sound knowledge of the transport environment required, but instruction about the potential consequence of the environment/patient interface is essential for medical transport teams. Knowledge of local geography and meteorology is also useful.

Team performance training should be based upon Crew Resource Management principles which incorporate effective communication skills, situational awareness, problem solving, decision making, stress recognition and management, team management, interpersonal skills, fatigue recognition and management [49]. Such training needs to be ongoing and tailored to conditions and experiences encountered within the patient transport service [50]. At least an above average level of physical fitness should be required of transport team members as well as regular pre deployment vision and hearing assessments.

Re accreditation of personnel should reflect clinical currency in out of hospital patient transportation, equipment familiarisation, participation in specific quality assurance activities, accuracy and completeness of documentation and participation in transport vehicle familiarisation briefings. Skills can be maintained through ongoing in hospital clinical exposure within relevant critical care environments, clinical exercises utilising transport equipment and team scenarios, supervised transports and simulator training. Regular attendance and participation in quality/audit activities should be required.

Overall, the use of specialised doctor staffed teams has been suggested to reduce adverse events and be associated with better transport outcomes [30,51,52]. Not all acutely ill patients require a doctor. Although out of keeping with most current accepted guidelines for minimum standards of patient transportation, non-medical escort can under medical guidance, transport some critically ill patients with no documented added morbidity or mortality [53]. On this basis hospital and non-hospital based IHPTS can deploy a multi tiered response capability, in terms of team crew composition and resource utilisation. Such a strategy would require reliable and expert pre transport information gathering and assessment. Currently, available scoring tools to predict which patient is not at risk [54] have a low specificity. Similarly, given the incidence of missed injuries [19,20,35] and deficiencies in treatment at the referral sites [17], such decisions for critically ill patients should be cautiously applied, if at all.

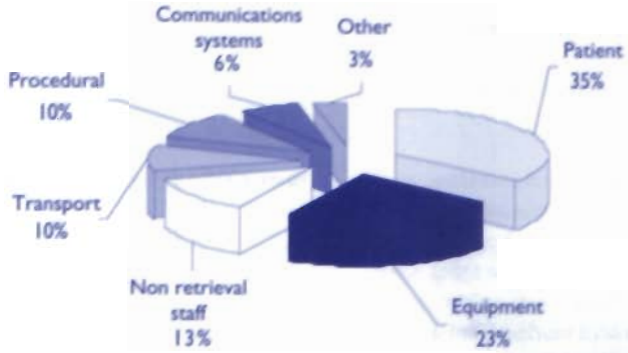

Figure 3. Type of inter-hospital patient transfer incident

Types of transport vehicles and vehicle selection

IHPTS may choose to operate from road ambulances, rotary wing (helicopters), fixed wing aircraft (dedicated air ambulances or commercial flights) or a combination.

Road ambulances are readily available and equipped to a varied degree based upon local needs [51]. Vehicle and available patient cabin size varies and is influenced by factors such as operational speed, manoeuvrability, local terrain and geography and vehicle initial and ongoing costs.

Helicopters are often selected based upon the considerations of the geographical environment it will be expected to work within, cost, maintenance, single/twin engine, size, noise, and IFR/nonIFR capability. A twin-engine aircraft has a significant margin of safety for medical work, in that it can fly on and land after an engine failure whereas a single engine aircraft has no option but to auto rotate into the nearest clear space. Any helicopter used for long distance patient transport over wilderness areas should be twin engined. An aircraft equipped to fly using visual flight rules (VFR) only is at a safety disadvantage compared to one with equipment and pilots trained to fly using instrument flight rules (IFR) when needed, either with two pilots or using an autopilot. Interhospital medical work is between known safe landing zones and there may be an advantage to using larger aircraft with the capacity more than one patient. Noise is an issue for hospitals in populated areas, and there is a benefit to modern quieter helicopters designed to minimise tail rotor noise (such as fenestron rotors or NOTAR [no tail rotor] systems).

Fixed wing aircraft range from dedicated or reconfigured turbo prop or jet engine aircraft fitted out as air ambulances, long haul commercial airliners, to stretchers mounted to military aircraft designed for transport of mass casualties.

Generally, road vehicles are more efficient and quicker for distances of up to 50 km, helicopter transport most efficient within the range of 50 – 250 km, whilst fixed wing aircraft are preferred for distances beyond that. Table 1 summarises the advantages and disadvantages of the various modes of patient transportation.

A new aircraft, the Bell/Agusta 609 Tiltrotor, combines advantages of both rotary and fixed wing aircraft and may have a significant impact on aeromedical work. It is designed as an essentially fixed wing aircraft, but with tilting wing mounted engine. It can take off from and land at a hospital helipad, and hover as a helicopter, then move its rotors into a rear thrust position for forward motion with the speed advantage of a fixed wing aircraft. Such aircraft may have a major impact on retrieval work from isolated rural facilities.

To date most documented adverse patient related events are influenced more by clinical rather than vehicle related factors [18]. The transport process, itself may however contribute to patient morbidity and mortality for certain patient groups [22,55], but the transport factors that contribute to this are as yet poorly defined.

Choice of vehicle for specific patient groups remains ill defined. Few comparisons between different modes of transportation have been done using similar patient population groups. For trauma patients, selection is dependent on severity of injury, with those with the highest severity of injury most likely to benefit from a helicopter transport, capable of delivering the patient to definitive care quicker than a road

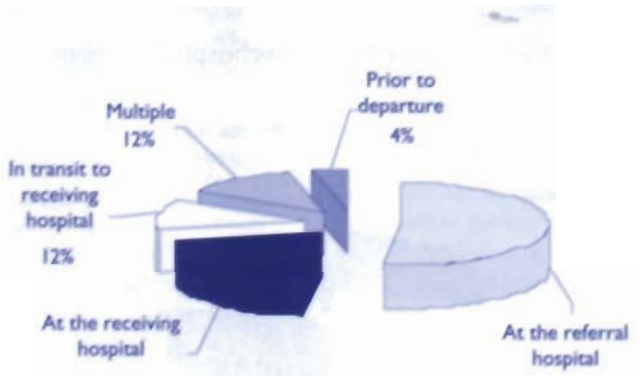

Figure 4. Location of inter-hospital patient transfer incident

vehicle. This benefit lessens as the time delay to request for transfer increases to beyond 60 minutes [52] and is likely to reflect a different trauma patient population. Another factor that influences this finding is the quality of initial care at the referral hospital [56].

Studies have shown the safety of transporting patients with acute coronary syndromes by helicopter [57]. Comparative studies with road transportation have not shown a survival advantage but fewer adverse cardiac events occur during road as compared to helicopter transport [58].

Patients with a broad case mix [52,59] with specific conditions such as hypothermia, post thrombolytic therapy, cardiogenic shock receiving complex therapy (i.e. inotropes and intraaortic balloon pump) and trauma has had documented safe transports. Of the latter, trauma patients are the group with the most consistent benefit. Time delays have been said to contribute to adverse patient outcomes [60-62], but not all studies support a timely transfer [63,64].

A comparison of patients with spinal injuries undergoing inter-hospital transfer by road, road/fixed wing and helicopter, showed that no form of transportation was associated with a documented exacerbation of neurological injury. Compared to road transport, helicopter transports were associated with fewer overall transport incidents, but a similar number of patient only related incidents [65].

In summary, based upon the available evidence, the main determinants for the choice of transport vehicle remains regional time dependent clinical factors, geography and vehicle service/maintenance requirements.

Patterns of referral

Each region should assess and monitor their potential requirements for inter-hospital patient transportation. Based upon this information a regional strategy can be formulated. It is crucial that such a strategy aims to reduce the burden of referral upon referring hospitals and does not contain financial or logistical disincentives for the appropriate referral and patient transport. It is equally important that tertiary referral centres are not "inundated" with patients who are not in specific need of tertiary medical care. This may arise as a result of inadequate allocation of resources to non-tertiary hospitals [60,65] and variations in referral practice amongst physicians [66]. Specific guidelines [26,67,68] and instructional courses improve transport decision-making and the confidence of referring staff to make patient transport decisions [62]. Examples of regional guidelines for inter-hospital transfer of trauma patients are those for the South Western Sydney Area Health Service [69], and guidelines for selection of level of patient escort [67].

The crucial step that determines effectiveness of any referral processes is accurate patient identification. This can be based upon the 5 "R"s (figure 2) of referral and patient transportation.

The greatest delays occur after patient arrival to the referral hospital and prior to IHPTS notification [60,69]. Unpublished data from the NRMA CareFlight (New South Wales, Australia) show median time till referral to be 3 hours (range 10 min to 7.5 hours). These delays may be due to failure to recognise need for transfer [70,71], communication difficulties with between referring and receiving hospitals [72] or administrative [71].

Demographic information have been used to predict Emergency Medical Services utilisation [73], population [74] and health [75] demographics to predict Emergency Department utilisation and population distribution data [76] to assess accessibility to helicopter based transport services. Combining such data with referral patterns into geographical mapping programmes may demonstrate current and future patient transport requirements. Geographical mapping of resource allocation – both type and quantities – can also be utilised during the planning stages by IHPTS.

Referral Communication, Patient and IHPTS preparation

The referring hospital staff need only make a single call [77,78], which then triggers a standardized process. This single contact point may be utilised as a source for immediate clinical advice [79], triage, tasking and preparation for patient transportation and reception at the receiving facility. Undirected telephone information transfer can be unreliable [80] and a standard format for information transfer enhances the quality and quantity of information exchanged [69,80,81]. An example of this is the NEWS ABCDEFGH checklist, which refers to the questions asked in relation to patient preparation, i.e. Needed? Enough? Working? Secure? about Airway (plus cervical spine), Breathing, Circulation, Disability, Equipment, Family, Gastric tube and History/handover [69].

These communication channels can be via a dedicated telephone landline, radio or Internet facilitated information transfer such as email, still and/or video picture transfer. A conferencing system can be established where referring, retrieval and receiving doctors and any coordinating personnel can simultaneously be part of the one call. Operational planning and clinical management advice [82] can then proceed simultaneously. For such a system to be efficient, it must run according to a set protocol. This protocol should define who will lead or "chair" the conversation. Ideally such conversations should be recorded, protected from liability and used for quality purposes. In situations where transport team dispatch is urgent, dispatched can occur whilst the other parties complete the exchange of information.

Telemedicine, especially in relation to radiology, is having an increasing impact upon the decision to transfer patients. Electronic transfer of high quality images can prevent unnecessary transfers and facilitate the transfer processes [83,84], decision-making and consultation processes for a number of acute and non-acute clinical conditions [85,86]. Increasingly, the associated technology is becoming less prohibitive from both financial and hardware requirements [86].

Receiving hospital specialists, to whose care the patient is being referred, in conjunction

with a senior member of the IHPTS should take joint responsibility for the process and define the indication for referral. This is a crucial step towards the timely, organised and safe transfer of the patient to an appropriate and prepared hospital. All necessary assistance (eg information, personnel and equipment) for the referral site should be offered at that time. A management plan which extends into the time after the arrival of the patient at the receiving hospital should also be developed at this stage. This process will provide all carers with therapeutic objectives, simplify the clinical interaction at each patient handover point and maintain continuity of care. If a patient is a well prepared, the transport team will not need to perform time consuming interventional procedures [87,88] prior to transportation, clinical information will be available and the patients clinical state well known to the transporting team prior to their arrival. The role of the team is then that of evaluation, continuation and monitoring of treatment, as well as communication with the receiving hospital. Those responsible for the referral process should remain readily contactable in case of alterations to the existing management plan or further advice.

The IHPTS team members must discuss, plan and prepare, as a team, for the known and potential logistical and operational challenges. All team members must be given an appropriate mission brief appropriately resourced and have performed necessary equipment and safety checks prior to departure.

Finally, before departing the referring hospital, he patient or surrogate is informed as to the reasons for the transfer and the transport processes and consent to the transport gained. Rural people being transferred to large urban centres as a result of a critical illness often experience anxiety and confusion [89]. In the USA it is now mandatory that written consent to transport be obtained [90]. In addition it must be confirmed that the transport is legal and does not violate regulatory requirements or managed care requirements. US federal legislation was passed in 1986 preventing "dumping" of uninsured patients, and this has now been amended within the Emergency Medical Treatment and Active Labor Act (EMTALA)[91].

Contraindications to different forms of patient transportation

There are very few specific contraindications. As discussed, there is no patient who is "too sick to transport" provided that patient receives appropriate in transit care and stands to benefit from the improved level of care at the receiving institution. While there are inherent risks in any transport, provided the benefits to the patient outweigh them there is no reason not to move. Choice of vehicle generally comes down to urgency, geography, weather and availability and often there is no one clear correct answer. At times more than one vehicle may be required.

Unpressurised aircraft (fixed wing or helicopter) are contraindicated for patients who will suffer from the decreased ambient pressure and expansion of any enclosed gas space, and for those in whom it is impossible to compensate for the relative hypoxia of altitude.

Specific patient groups for consideration include:

Decompression illness (DCI) and arterial gas embolism. Further depressurisation may exacerbate neurological DCI. Air transport should be by fixed wing aircraft capable of pressurisation to sea level cabin pressure (or to the ambient pressure of the referring institution), or low level helicopter flight if the weather is good, aviation restrictions allow it and it is possible to stay at sea level to the receiving institution. Road transport may be preferable, but local geography must be understood, with no area of increased altitude between referring and receiving institutions.

Other undrained, enclosed gas spaces. Any pneumothorax must be drained before air transport. There is a relative risk of bowel distension and rupture in patients with bowel obstruction. For patients with open eye injuries, there is no convincing evidence of risk for air transport in this group.

Spinal and spinal cord injuries. Helicopters tend to be preferred for patients with unstable spinal injuries. The concern is whether lateral and vertical shear forces, from corners and bumps during road transport, will exacerbate a spinal cord injury. There is no evidence that helicopter transport has a neurological advantage over a well driven ambulance [92] but is associated with fewer incidents [65].

Significant respiratory failure with hypoxaemia. If a patient is hypoxaemic despite maximal support (100% oxygen, optimal PEEP, recruitment manoeuvres, prone) he or she may not tolerate a more hypobaric environment. Transport is therefore limited to an aircraft that can be pressurised to at least the ambient pressure of the referring institution, although risk of hypoxia will still remain high.

Patient contaminated with biological and/or chemical hazards. Patients contaminated with biological and/or chemical hazards may excrete such hazards through contaminated clothing, skin, gastric secretions or exhaled air, all of which can potentially affect the performance of members of the transport team. Pilots are at a greater risk as their operational capacity can not only be affected by the hazard, but also performance may be impaired by the necessary biohazard personal protective measures. Efficient scavenging systems in aircraft are very difficult to apply, unless an efficient biohazard absorbent device can be utilised.

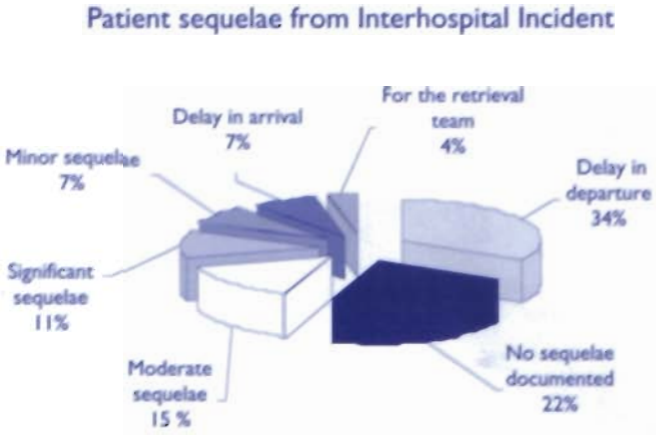

Figure 5. Documented patient sequel from interhospital patient transfer incidents

Monitoring Equipment

Even though guidelines for minimum standards of patient monitoring exist [25,28] they are, not consistently applied [44]. The transport environment is unforgiving to patient monitors, and few have been developed specifically for such a harsh environment. IHPTS have developed innovative structures, such as the stretcher bridge [95] to incorporate patient monitors into the transport environment. Data from clinical incident monitoring during patient transportation shows equipment related incidents to be 27% of all reported

critically ill patients has many interfaces, i.e. referral staff to receiving staff, referral staff to transport team, referral patient, monitoring/equipment to transport patient monitoring/equipment, etc and an audit process would need to encompass all such interfaces as well as involve all key stakeholders. Consideration should be given during the development of quality measures to each regions unique circumstances.

Examples of data acquisition for such audit processes are confidential surveys, the use of expert non-operational observers [49], and incident monitoring. Incident monitoring was initially developed to reduce accidents in military aviation and is well established in commercial aviation and more recently in the critical care areas of Anaesthesia [105], Intensive Care [106] and Emergency Medicine. Anonymous reporting of incidents can identify, monitor and improve process quality by using corrective strategies to close the loop and through ongoing incident reporting examine the extent of such change. Incident reporting can be applied as almost real time reporting by frequent feedback of trends and accumulated incidents.

Other specific parameters which are used to examine process performance (e.g. time periods in relation to tasking, response, time at scene, etc), system evaluation (e.g. delayed referrals, referrals due to lack of available resources, delays in patient acceptance to and at receiving location, task cancellation/diversion, clinically futile transfers, etc), vehicle performance and selection, crew performance (e.g. clinical errors, communication errors, documentation, completion of routine tasks such as equipment checks), and equipment performance. Quality measures should ideally be matched with patient illness and outcome measures. The latter can include ICU severity of illness measures, trauma scoring systems and associated predictors of outcome, generic hospital data such as DRGs, outcome, length of stay and resource utilisation/cost.

Often the difficulty with the collection of such variables is consistency. With the many interfaces during patient referral and transfer, and the variety of personnel, problems with consistency in data acquisition and definitions are not uncommon. Another difficulty is linkage that is linking transport data with that collected by affiliated sources (eg receiving hospital ICU illness measures, trauma databases, etc).

The NRMA CareFlight, in conjunction with the Australian Patient Safety Foundation, has utilised incident monitoring. Other IHPTS have also been contributing. Documentation of incidents is by the transporting team members. Examples of the available data are illustrated in figures 3 to 5. Figure 3 illustrates the type of each incident, figure 4 the location and figure 5 the patient sequelae as determined by the transporting team members. Moderate or more severe consequences are documented for 26% with delays in departure from the referral hospital accounting for 35% of incidents.

Table 2. Environmental stressors that can impact upon medical monitors used during transportation

Transport environmental factors impacting upon patient monitors.
Changes in barometric pressure
Changes in temperature
Changes in humidity
Ambient noise and hearing protection, preventing recognition of alarms
High frequency vibration, low frequency vibration (eg jolts)
Acceleration/deceleration forces
Radiofrequency transmitting equipment
Available power supply
Transport vehicle weight restrictions
Aviation and road regulatory requirements eg ability to be secured and sustain directional forces
Transport lighting conditions
Transport time
Medical gas supply limitations
Transport vehicle height restrictions eg urinary and pleural catheter drainage, external ventricular drains
Transport vehicle space limitations

With any quality assurance process there needs to be a closure of the loop. This should include all involved in the referral and transportation phases. Patient outcomes and evaluations of the referral and transport processes can be provided soon after patient transfer, whilst the transfer is still fresh in the minds of all those involved. Real time recording of incidents and adverse events would allow for prompt follow up and resolution of antecedents.

Cost

Measuring the cost benefit of a IHPTS used solely for inter-hospital transportation is difficult as the patient population who are most likely to benefit is poorly defined. For prehospital, scene responses, it is estimated that a helicopter service must save approximately 3 lives per year to be cost effective [107]. Although a small and possibly achievable number, 90% of transported patients are thought to not benefit directly from helicopter transfer, with obstetric emergencies, very young patients with acute respiratory problems and life threatening infections benefiting the most, in terms of life years and quality adjusted life years gained [59].

Regionalization of specialty services, eg trauma, neonatal, paediatric cardiac, etc has resulted in documented reduction in patient mortality. Regionalization and equity of access to health care however may not be possible in the absence of an efficient IHPTS. This is more obvious in rural trauma where time to definitive care and mortality is greater [107] and the removal of a pre existing IHPTS has been associated with increased injury mortality [108]. The cost benefit per year of life saved through regionalization of such services appears to be more than adequate to fund a regional specialised patient transport organization and thus provide for injured members of the rural community. The community's attitude to such a helicopter service is a positive one, with a greater willingness to pay through additional taxation burden amongst residents in remote areas, who base that willingness upon a perceived overall community benefit from such a service, a means of maintaining an equal access to health care services and a reassurance from its presence. A willingness to pay was also present when the threat of removal of such a service was suggested [109].

The risks and potential loss of crew and patient life years as a result of accident and injury during patient transportation may negate any added benefit. The current emergency medical helicopter accident fatality rate is approximately 4 – 6 per 100 000 flight hours, with non-fatal accidents being approximately ten times greater.

In summary, regional factors have a large impact upon the cost effectiveness of the IHPTS. Evaluation of such factors is essential for the optimal utilisation of such a service within a specified region. From perspective of public policy the benefits of regionalization needs to be balanced with the maintenance of equity of health care services provision. The equitable delivery of regional services for remote population should also be included as an outcome measure. Not disadvantaging any population group, or a community's perception of a disadvantage, as well as consideration of the clinical selection of patients and their outcome is to influence the measures of benefit for the different modes of transportation.

Future Challenges

The future challenges for IHPTS will arise from increasing patient complexity and severity of illness due to an aging population, regionalization of specialty, higher level, medical services and fiscal restraints. Similarly, challenges will arise from new therapeutic and/or diagnostic modalities that are increasingly complex, costly and require unique expertise for their clinical application

and thus less likely to be distributed widely. The development of regional health critical care networks and resultant redistribution of patients within those networks as a means to improve global critical care resource utilisation will create challenges of patient triage for referral, transport and receiving location. Also, the future may see distribution occurring not only over regions, but also nationally and even globally. This would test IHPTS capability over greater distances and transport duration.

The implications for IHPTS will be in terms of team selection, composition, training (medical and operational), experience, supervision and accreditation as well as transport vehicle and medical equipment selection and utilisation. Transporting staff will need to master the skills with managing of new transport technology, such as mobile extra corporeal support devices and electronic information. For example, electronic patient records [110], telemedicine [111], geographic information systems which utilise existing mapping programmes [112] and aviation navigational aids and can contribute valuable information to patient referral patterns for future service enhancement. Such developments can give rise to further challenges. For example, teleradiology can result in circumstances whereby the patient in one location has digital only x-ray images processed and transferred to another for reporting and the patient themselves is then transferred to a different location. Without prior planning to ensure the appropriate links are in place, the end result may be referral, transporting and receiving medical staff encountering the patient but never sighting the X-rays, other than a distant verbal or written report. Future electronic technology must ensure compatibility and ability to perform optimally within the transport environment and range of vehicles.

Through the demand for a higher level and cost effective outcome and the use of complex technology from a variety of specialties, Inter-hospital patient transportation has evolved into a unique medical sub specialty. IHPTS have the potential to expand into tasks other than inter-hospital patient transportation. Their ability to be quickly mobilised, expertise and familiarity within the transport environment, care of the critically ill, communication skills and devices, transport medical equipment and quality processes is applicable to direct scene responses and response to medical disasters [113,114].

A strong interaction between medical and operational transport arms will enable an effective adoption of common outcome aims, quality measuring tools and integrated crew resource management training. M can be learnt, borrowed and utilised from the commercial aviation industry's experience with incident monitoring and simulation training by the medical transport arm.

As the number of IHPTS continues to increase, a collaborative exchange of information between dedicated IHPTS becomes an increasingly valuable exchange. An Internet based forum specific for patient transportation is currently available [115].

Conclusion

IHPTS are a unique collaboration between clinical and operational transport systems. The utilisation of such services has received much scrutiny in the past. However the role of such services is continually changing, driven largely by the realisation of the clinical requirements required for safe patient transportation, the changing nature of critically ill patients and health resource distribution, networking of critical care and other specialty services and public perceptions and expectations. This has had, and will continual to have, significant implications as to the evolving organisational structure, crew selection and training, equipment, patient selection and quality assurance for IHPTS. The clinical component has much to gain by borrowing from the examples set by the aviation component in some of these areas.

It is important for each regional health service to evaluate, determine and develop it's own patient referral/transport requirements and an accessible process for all such referrals, incorporating the most appropriate regional IHPTS. Subsequent evaluation will further define which patients will directly benefit and the preferred modes of transportation. Collaboration between IHPTS through information sharing, training, equipment evaluation, audit and guideline development is crucial for their future development. In keeping with past and future progress, strong consideration should be given to the future recognition of out of hospital patient transportation as a unique and important aspect of critical care medicine in terms of formal education, accreditation and research status.

References

Thompson DR, Clemmer TP, Applefeld JJ, et al. 1994. Regionalization of critical care medicine: task force report of the American College of Critical Care Medicine. Crit Care Med 22:1306-13.

Pearson G, Shann F, Barry P, et al. 1997. Should paediatric intensive care be centralised? Trent versus Victoria. Lancet 349:1213-7.

Pollack MM, Alexander SR, Clarke N, et al. 1991. Improved outcomes from tertiary centre pediatric intensive care: a statewide comparison of tertiary and non tertiary care facilities. Crit Care Med 19:150-9.

Jurkovich GJ, Mock C. 1999. Systematic review of trauma system effectiveness based on registry comparisons. J. Trauma 47(suppl 3):s46-s55.

Mullins RJ, Mann NC. 1999. Population based research assessing the effectiveness of trauma systems. J. Trauma 47(suppl 3):s59-s66.

Stroke Unit Trialists' Collaboration. 1997. Collaborative systematic review of the randomised trials of organised inpatient (stroke unit) care after stroke. BMJ. 314:1151-59.

Baker SP, Whitfield RA, O'Neil B. 1987. Geographic variations in mortality from motor vehicle crashes. N Engl J Med. 316:1384-87.

Baker SP, Whitfield RA, O'Neil B. 1988. County mapping of injury mortality. J Trauma. 28:741-45.

Public Health Division. The Health of the people of New South Wales – Report of the chief Health Officer. Sydney: NSW Department of Health. 2003. http://www.health.nsw.gov.au/public-health/chorep/toc/chondex.htm.

Grossman DC, Hart LG, Rivara FP, et al.1995. From roadside to bedside: the regionalization of trauma care in a remote rural county. J Trauma.38:19-21

Golden Bruce. Joint Venture, Aviation Medicine in New Zealand. 1997 LJ & CM Thompson, Auckland New Zealand. ISBN 0-473-04215-0

Taylor JO, Landers CF, Chuday JD, et al 1970. Monitoring high-risk cardiac patients during transportation in hospital Lancet. 2:1205-1208.

Waddell G, Scott PDR, Lees NW, et al 1975 Effects of ambulance transport in critically ill patients. Br Med J. 1:386-389.

Gilligan JE, McCleave D, Nicholson B, et al. 1977 Retrieval of the critically ill in South Australia: a coordinated approach. Med J Aust. 2:849-855.

Pearl RG, Mihm FG, Rosenthal MH. 1987 Care of the adult patient during transport. Int Anesthesiol Clin. 25:43-75

Gentleman D, Jennett B. 1981. Hazards of inter-hospital transfer of comatose head injured patients. Lancet 2:853-4.

Olson CM, Jastremski MS, Vilogi JP, et al. 1987. Stabilization of patients prior to interhospital transfer. Ann J Emerg Med 5:33-9.

Henning R, McNamara V. 1991. Difficulties encountered in transport of the critically ill child Paed Emerg Care. 7:133-7.

Dunn LT. 1997. Secondary insults during the interhospital transfer of head injured patients: an audit of transfers in the Mersey Region. Injury 28:427-31

Henderson A., Coyne T., Wall D. et al. A survey of interhospital transfer of head injured patients with inadequately treated life-threatening extracranial injuries, Aust NZ J Surg, 1992, 62:759-762.

Ridley S, Carter R. 1989. The effects of secondary transport on critically ill patients. Anaesth 44:822-7.

Filabouris A. 1999. Patient referral and transportation to a regional tertiary ICU: patient demographics, severity of illness and outcome comparison with non-transported patients. Anaesth Inten Care. 27:385-90

Andrews PJ, Piper IR, Dearden NM, et al. 1990. Secondary insults during intrahospital transport of head injured patients. Lancet. 335:327-30.

Edge WE, Kanter RK, Weigle CG, et al. 1994. Reduction of morbidity in interhospital transport by specialised paediatric staff. Crit Care Med. 22:1186-91.

Australian and New Zealand College of Anaesthetists and Australian College of Emergency Medicine 1996 Minimum standards for transport of the critically ill (P23). Melbourne. ANZCA.

The Association of Anaesthetists of Great Britain and Ireland. Recommendations for the transfer of patients with Acute Head Injuries to Neurosurgical Units. 1996. The Association of Anaesthetists of Great Britain and Ireland.

The Intensive Care Society. Guidelines for Transport of the Critically ill adult. 1997. The Intensive Care Society.

Guidelines Committee of the American College of Critical Care Medicine. 1993. Guidelines for the transfer of critically ill patients. Crit Care Med 21:931-37

Johnson CM, Gonyea MT. 1993. Transport of the critically ill child. Mayo Clin Proc 68:982-87.

Bellingan G, Olivier T, Batson S, et al. 2000. Comparison of a specialist retrieval team with current United Kingdom practice for the transport of critically ill patients. Intens Care Med 26:740-4

31. Havill JH, Hyde PR, Forrest C. 1995. Transport of the critically ill patient: an example of an integrated model. NZ Med J.108:378-80
32. Duke GJ, Green JV. 2001. Outcome of critically ill patients undergoing interhospital transfer. Med J Aust 174:122-5
33. Kinsella JP, Griebel J, Schmidy JM, et al. 2002.Use of inhaled nitric oxide during interhospital transport of newborns with hypoxemic respiratory failure. Pediatrics 109:158-61.
34. Cicero J 3rd, Hartz RS, Sanders JH Jr, et al. 1985. Interhospital transport of patients with ongoing intraaortic balloon pumping. Am J Cardiol. 56:59-61.
35. Duke JH, Clarke WP. 1981. A university staffed private hospital based air transport service. Arch Surg 116:703-8
36. Farnell MB, Sachs JL. 1989. Mayo Clinic's hospital based emergency air medical transport service. Mayo Clinic Proc 64:1213-25.
37. Burrell AR, Haynes SB, Wilson RD. 1989. A rural retrieval service. Anaesth Intensive Care. 17:175-9
38. Gilligan JE. Griggs WM, Jelly MT. et al. 1999. Mobile intensive care services in rural South Australia. Med J Aust. 171:617-20.
39. Simpson DA. Heyworth JS. McLean AJ. et al 1988. *Extradural haemorrhage: strategies for management in remote places.* Injury. 19:307-12.
40. Thomas SH, Orf J, Peterson C, et al. 2000. Frequency and costs of laboratory and radiograph repetition in trauma patients undergoing interfacility transfer. Am J Emerg Med. 18:156-8
41. Rashid A. Bhuta T. Berry A. 1999 A regionalised transport service, the way ahead? Arch Dis in Childhood. 80:488-92
42. Harris BH. 1986. Performance of aeromedical crewmembers: training or experience. Am J of Emerg Med. 4:409-11
43. Low RB, Dunne MJ, Blumen IJ, et al. 1991. Factors associated with the safety of EMS helicopters. Am J of Emerg Med 9:103-6
44. Knowles PR, Bryden DC, Kirkhen R, et al. 1999. Meeting the standards for interhospital transfer of adults with severe head injury in the United Kingdom. Anaesth 54:283-89
45. Roncin CJ, Reeve WR, Wallace PGM. 1992. Preparation of the critically ill for interhospital transfer. Anaesthesia. 47:327-31
46. Beddingfield FC, Garrison HG, Manning JE, et al. 1996. Factors associated with prolongation of transport times of emergency pediatric patients requiring transfer to a tertiary care centre. Pediatr Emerg Care.12:416-19
47. Donahue A, Flabouris A, Marren A. 2002. Impact of patient preparation, TISS-28 and extent of active resuscitation upon retrieval team scene time during interhospital transfer. (Unpub)
48. Prince C, Salas E. 1993. Training and research for teamwork in the military aircrew. In Cockpit Resource Management. Ed Wiener EL, Kanki BG and Helmreich RL Academic Press. Orlando, FL
49. Helmreich RL, Merrit AC, Wilhelm JA. 1999. The evolution of crew resource management in commercial aviation. Int J Aviat Psychol. 9:19-32.
50. Helmreich RL. 2000 On error management: lessons from aviation. BMJ 320:781-5
51. Gebremichael M, Borg U, Habashi NM, et al. 2000 Interhospital/transport of the extremely ill patient: The mobile intensive care unit. Crit Care Med. 28:79-85
52. Arfken CL, Shapiro MJ, Bessey PQ, 1998 Effectiveness of helicopter versus ground ambulance services for interfacility transport J Trauma. 45:785-90
53. Beyer III AJ, Land G, Zaritsky A. 1992 Non physician transport of intubated pediatric patients: a system evaluation. Crit Care Med 20:961-66.
54. Marx G, Vangerow B, Hecker H, et al. 1998 Predictors of respiratory function deterioration after transfer of critically ill patients. Intens Care Med 24:1157-62
55. Surgenor SD, Clerico T, Corwin HL. 1999. Critical care in a rural setting: survival of patients transferred to a tertiary care ICU. Abstract in Crit Care Med. 27 (Suppl 1):A64
56. Sampalis JS, Denis R, Lavoie A, et al. 1999.Trauma care regionalization: A process outcome evaluation J Trauma 46:565-79
57. Sternbach G. Sumchai AP. 1989. Is aeromedical transport of patients during acute myocardial infarction safe? J of Emerg Med 7:73-7
58. Stone CK. Hunt RC. Sousa JA. et al. 1994. Interhospital transfer of cardiac patients: does air transport make a difference? Air Med Journal. 13:159-64
59. Hotvedt R, Kristiansen IS, Forde OH, et al. 1996. Which groups of patients benefit from helicopter evacuation? Lancet 347:1362-66
60. Deane SA, Gaudry PL, Woods WP, et al.1990. Interhospital transfer in the management of acute trauma. Aust NZ J Surg. 60:641-6
61. O'Sullivan MG, Gray WP, Buckley TF. 1990. Extradural haematoma in the Irish Republic: an analysis of 82 cases with emphasis on "delay". British J of Surg. 77:1391-4
62. Poon WS, Li AK. 1991. Comparison of management outcome of primary and secondary referred patients with traumatic extradural haematoma in a neurosurgical unit. Injury. 22:323-5
63. Kearney PA, Terry L, Burney RE. 1991. Outcome of patients with blunt trauma transferred after diagnostic or treatment procedures or four hour delay. Ann Emerg Med.20:882-6.
64. Veenema KR. Rodewald LE. 1995. Stabilization of rural multiple-trauma patients at level III emergency departments before transfer to a regional trauma centre. Ann Emerg Med. 25:175-81
65. Flabouris A. 2001. Clinical features, patterns of referral and out of hospital transport events for patients with suspected isolated spinal injury. Injury 32:569-575
66. Richardson DK, Gabbe SG, Wind Y. 1984. Decision analysis of high risk patient referral. Obst Gyne. 63:496-501
67. Lee A, Lum ME, Beehan SJ, et al. 1996. Interhospital transfers: Decision-making in critical care areas. Crit Care Med. 24:618-22
68. Neurosurgical Society of Australasia and the Royal Australasian College of Surgeons; The management of acute neurotrauma in rural and remote locations: A set of guidelines for the care of head and spinal injuries. 2000. http://www.nsa.on.net/Rural.pdf
69. Injury Advisory Committee, South Western Sydney Area Health Service: Interhospital Trauma Transfers. 2002. http://www.swsahs.nsw.gov.au/livtrauma/files/BPGAug01.pdf
70. New South Wales Department of Health. (1996a). Management guidelines for people with burn injury. Pub No. ISBN 0731092155. 1991. Sydney Australia
71. Marsh H, Maurice-Williams RS, Hatfield R. 1989. Closed head injuries: where does delay occur in the process of transfer to neurosurgical care? Br J Neurosurg 3:13-19
Vyvan HAL, Kee S, Bristow A. 1991. A survey of secondary transfers of head injured patients in the South of England. Anaesthesia 46:728-31
Su S. Shih CL. 2002. Resource allocation in an emergency medical service using computer simulation. Am J of Emerg Med. 20:627-34
72. Reeder T, Locascio E, Tucker J, et al. 2002. ED utilisation: the effect of changing demographics from 1992 to 2000. Am J of Emerg Med. 20:583-7
Bibi H, Nutman A, Shoseyov D, et al. 2002. Prediction of emergency department visits for respiratory symptoms using artificial neural network. Chest. 122:1627-32
Heggestad T, Borsheim KY. 2002. Accessibility and distribution of the Norwegian National Air Emergency Service. 1988-98. Air Med Journal. 21:39-45
Sugrue M. 2000. A one call wonder or a white elephant? Interhospital Transfer Hotline. ANZ J Surg. 70(suppl):A146-7.
78. Nocera N. 1998. Interhospital trauma transfer and a trauma hotline system – does it work? Trauma Grapevine 1:6-7
79. Owen H. Duncan AW. 1983. Towards safer transport of sick and injured children. Anaesth Intens Care. 11:113-7
80. Walters KA. 1993. Telephoned head injurey referrals: the need to improve the quality of information provided. Arch of Emerg Med. 10:29-34
81. Keany J, Fitzpatrick MO, Beard D, et al. 2000. A standardised neurosurgical referral letter for the inter-hospital transfer of head injured patients. J Acc Emerg Med. 17:257-60
82. Henning R. 1992. Emergency transport of critically ill children: stabilisation before departure Med J of Aust. 156:117-24
83. Spencer JA, Dobson D, Hoare M, et al. 1991. The use of computerised image transfer system linking a regional neuroradiology centre to its district hospitals.Clin Radiol. 44:342-4
84. Lee T, Latham J, Kerr RS, et al. 1990. Effect of a new computed tomographic image transfer system on management of referrals to a regional neurosurgical service. Lancet. 336:101-3
85. Levine S, Gorman M. 1999. "Telestroke": the application of telemedicine to stroke. Stroke. 30:464-9
86. Perednia DA, Allen A. 1995. Telemedicine technology and clinical applications. JAMA. 273:483-88
87. Leicht MJ, Dula DJ, Bratman S, et al. 1986. Rural interhospital helicopter transport of motor vehicle trauma victims: causes for delays and recommendations. Ann Emerg Med.15:450-3
88. Ehrenwerth J, Sorbo S, Hackel A. 1986. Transport of critically ill adults. Crit care Med. 14:543-47
89. Johnson P. 1999. Rural people's experience of critical illness involving inter-hospital transportation a qualitative study. Aust Crit Care. 12:12-6.
90. Strobos J. 1991 Tightening the screw: statutort and legal supervision of interhospital patient transfers. Ann Emerg Med. 20:302-310.
91. Clemmer TP. (editorial) 2000. Transport of the critically ill. Crit Care Med. 2000, 28:265-266
92. Burney RE, Waggoner R, Maynard FM. 1989. Stabilization of Spinal Injury for Early Transfer. J Trauma.29:1497-99
93. Uusaro A, Parviainen I, Takala J, et al. 2002. Safe long distance interhospital ground transfer of critically ill patients with acute severe unstable respiratory and circulatory failure. Intensiv Care Med 28:1122-25
94. Flabouris A, Schoetkar P, Garner A. ARDS with severe hypoxia - Aeromedical transportation during prone ventilation (submitted for publication)
95. Wishaw KJ, Munford BJ, Roby HP. 1990. The CareFlight Stretcher Bridge: a compact mobile intensive care unit. Anaesth. Intens. Care. 18:234-8
96. Webb RK, Russell WJ, Klepper I, et al 1993. Equipment failure: an analysis of 2000 incident reports. Anaesth Intens Care 21:673-677
97. Lawless ST. 1994. Crying wolf: false alarms in a paediatric intensive care unit. Crit Care Med. 22:981-5
98. Benitt LR. Santora TA. Leverle BJ. et al 1990. Accuracy and utility of pulse oximetry in the surgical intensive care unit. Curr Surg. 47:267-8
99. Bruckart JE. 1992. Radiated electrical field measurements in U.S Army helicopters. Aviat Space Environ Med. 63:1019-23
100. Fromm RE, Cambell E, Schlieter P. 1995. Inadequacy of visual alarms in helicopter air medical transport. Aviat Space Environ Med 66:784-6
101. Herr DM, Newton MC, Santrach PJ, et al 1995. Airborne and rescue point of care testing. Am J Clin Pathol 104(suppl 1):554-558
102. Kendall J, Reeves B, Clancy M. 1998 Point of care testing: randomised controlled trial of clinical outcome BMJ. 316:1052-7
103. Lichtenstein D, Courret JP. 1998 Feasibility of ultrasound in the helicopter. Intensive Care Med 24:1119
104. Caldwell JA Jr, Lewis JA. 1995. The feasibility of collecting in flight EEG data from helicopter pilots. Aviat Space Environ Med. 66:883-9
105. Runciman WB, Sellen A, Webb RK, et al 1993. Errors, Incidents and accidents in anaesthetic practice. Anaesth Intensive Care. 21:506-19
106. Beckmann U, Baldwin I, Hart GK, et al 1996 The Australian Incident Monitoring Study in Intensive Care: AIMS-ICU. An analysis of the first year of reporting. Anaesth intensive Care 24:320-29
107. Rogers FB, Shackford SR, Osler TM, et al 1999. Rural trauma: the challenge for the next decade. J Trauma 47:802-21
108. Mann NC, Pinkey KA, Price DD, et al. 2002. Injury mortality following the loss of air medical support for rural interhospital transport. Acad Emerg Med. 9:694-8
109. Olsen JA, Donaldson C. 1998. Helicopters, hearts and hips: using willingness to pay to set priorities for public sector health care programmes. Soc Sci Med. 46:1-12
110. Ambulance Service of New South Wales 2001/02 Annual Report. Sydney, Australia ISSN 0734732406. 2002. http://www.health.nsw.gov.au/areas/ambulance/otherdocs/annualreport2002.pdf
111. Yamamoto LG. Inaba AS. DiMauro R. 1994 Personal computer teleradiology interhospital image transmission to facilitate tertiary pediatric telephone consultation and patient transfer: soft-tissue lateral neck and elbow radiographs. Ped Emerg Care. 10:273-7.
112. Lerner EB, Billittier AJ, Sikora J, et al 1999. Use of a geographical information system to determine appropriate means of trauma patient transport Acad Emerg Med. 6:1127-33.
113. Nocera A, Dalton AM. 1994. Disaster Alert! The role of physician staffed helicopter emergency services. Med J of Aust. 161:689-92
114. Martchenke J, Lynch T, Pointer J, et al 1995. Aeromedical helicopter use following the 1989 Loma Prieta earthquake. Aviat Space Environ Med. 66:359-63
115. http://www3.health.nsw.gov.au/nswhealthforum/ListForums.cfm?CFApp=2