

# **VALIDATION OF THE PAEDIATRIC TRIAGE TAPE**

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## Declaration

I confirm that *Validation of the Paediatric Triage Tape* is entirely my own work. Where other authors have contributed, their input has been appropriately acknowledged. I confirm that I hold the degree MBChB from the University of Edinburgh.

I confirm that I have not submitted this thesis for any other degree, diploma or professional qualification.

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Signature

Date         01 06 2006

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## Abstract

Assessment of physiological parameters forms an essential part of the clinical assessment of an injured or ill child. However, the evidence base for the values that we currently accept and teach as “normal” ranges of heart rate and respiratory rate is poor. This thesis studied 1109 healthy, resting schoolchildren aged four to 16 years in Plymouth, England, and derived reference ranges of heart rate and respiratory rate from this sample.

A study was then undertaken in a deprived area of Cape Town, South Africa, to examine the heart and respiratory rates of 346 healthy, resting schoolchildren aged five to 16 years. This sample was similar by height and weight to the British sample, and their heart and respiratory rates were compared. There was no difference in median heart rate in the two groups, but a small statistically significant difference in respiratory rate. However, this difference was too small to be clinically significant, being less than one breath per minute.

As there were no differences in physiology between the two countries, the validation of the Paediatric Triage Tape could take place in South Africa and the results be applied in the United Kingdom.

The third stage of this thesis consisted of a Delphi study to derive consensus based criteria against which major incident triage tools may be tested, as the current testing standards (most commonly, the Injury Severity Score (ISS)) are not appropriate for use in a major incident setting. The criteria thus derived were used as part of the validation process for the Paediatric Triage Tape (PTT), a simple to use vinyl tape that is used for primary triage of children in major incident situations. The

validation also proceeded against more typical measurement standards, including the ISS.

The validation took place in Cape Town, against a prospective sample of 3461 injured children. The PTT was found to have very poor sensitivity (that is, it missed many of the seriously injured children and many of the children in need of immediate medical intervention), although it had excellent specificity. The overtriage and undertriage rates were within the limits currently held to be acceptable. The PTT was compared to other major incident triage tools and found to have similar performance to Careflight methodology. Both the START and JumpSTART algorithms performed very poorly and should be discontinued from use.

The PTT needs redesigning and revalidating, or replacing by a more robust primary triage tool. In the meantime, all primary triage tools for children in this setting should be used with caution.

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## List of Abbreviations

ACSCOT	American College of Surgeons Committee on Trauma
AIS	Abbreviated Injury Scale
APLS	Advanced Paediatric Life Support
ASPTS	Age Specific Paediatric Trauma Score
ATLS	Advanced Trauma Life Support
CCS	Casualty Clearing Station
CRT	Capillary Refill Time
GCS	Glasgow Coma Score
HR	Heart Rate
ISS	Injury Severity Score
MOF	Multi-Organ Failure
NISS	New Injury Severity Score
NPV	Negative Predictive Value
PPV	Positive Predictive Value
PTS	Paediatric Trauma Score
PTT	Paediatric Triage Tape
RR	Respiratory Rate
RTS	Revised Trauma Score
RXH	Red Cross War Memorial Children's Hospital
SBP	Systolic Blood Pressure
START	Simplified Triage And Rapid Treatment
TRTS	Triage Revised Trauma Score
TS	Trauma Score
UCT	University of Cape Town

## **CHAPTER 1:**

### **INTRODUCTION**

- 1-1 Major Incidents
  - 1-1-1 Management Priorities at Major Incidents
  - 1-1-2 Triage at Major Incidents
    - 1-1-2a Triage Priorities
    - 1-1-2b Triage Systems
    - 1-1-2c Triage in Children
- 1-2 Physiological Reference Ranges in Children
- 1-3 Standards Against Which to Validate Triage Tools
- 1-4 Choice of Location for Validation of the Paediatric Triage Tape
- 1-5 Aim
- 1-6 Summary

## **1-1: Major incidents**

The tsunami of 26 December, 2004 will long be remembered for the number of deaths that it caused (over 250,000). Although this single incident contributed to the total of four times the number of deaths from disaster in comparison with 2003 (CRED, 2005a), the total number of people affected by such events each year is many times higher. According to the World Health Organisation's Centre for Research on Epidemiology of Disasters, disasters and mass casualty situations are becoming commoner, and are affecting more people (CRED, 2005b). An incredible 254 million people were affected by disaster in 2003 (CRED, 2005c): in 2004, there were 97 major floods recorded, along with 75 wind storms (hurricanes) and 28 earthquakes, causing a total of \$88 billion in damages (CRED, 2005c). The majority of disasters tend to occur in developing countries, but almost 20% of 2004's disasters occurred in the United States of America (CRED, 2005a); the floods in New Orleans (September 2005) served as a prime example.

Whilst a disaster is typically thought of as a naturally occurring event (such as an earthquake or tidal wave), a mass casualty situation may occur from a natural or man-made source (such as a mass transportation collision, or industrial fire). In the United Kingdom (UK), where natural disasters are rare, mass casualty situations tend to be referred to as Major Incidents. For the Health Services a major incident is

“any occurrence which presents a serious threat to the health of the community, disruption to the service or causes (or is likely to cause) such numbers or types of casualties as to require special arrangements to be implemented by hospitals, ambulance services or health authorities” (Department of Health, 2005).

This definition is intentionally broad, to cover dealing with incidents from food poisoning outbreaks through to planning for mass gatherings. However, major

incidents are generally regarded as events which are unpredictable, sudden and which result in a large number of injured or ill casualties presenting to the emergency services over a short period of time. Such events in the recent past in the UK have included stadium disasters (Wardrope et al, 1990), passenger transportation crashes (Kirsh et al, 1989), terrorist bombings (Dearden, 2005), and industrial incidents (Carley et al, 1998).

The point at which a major incident occurs is dependent upon the ability of health service resources at the time of the incident to cope with the patient workload (Advanced Life Support Group, 2002). Major incidents may therefore occur with relatively small numbers of casualties if resources are scarce: this is particularly likely to occur in developing countries where healthcare resources are limited at the best of times. The health services definition also takes into account the severity of injury, as an incident resulting in a small number of casualties may require a major incident response if they are all severely injured.

An average of three to four major incidents occur in the UK each year (range zero to eleven) – although this is likely to be an underestimation – and these typically produce injuries rather than ill patients (Carley and Mackway-Jones, 1997; Carley et al, 1998). Many major incidents involve large numbers of children as part or all of the casualty load (van Amerongen et al, 1993; Wass et al, 1994; Carley and Mackway-Jones, 1997; Brown and Marshall, 1988; Mallonee et al, 1996; Sklar, 1987). For this thesis, which is concerned with the triage of children in such situations, the term major incident will be applied to any mass casualty situation.

### **1-1-1: Management Priorities at Major Incidents**

Contrary to the day-to-day work of health care professionals, patient care is not the first priority at the scene of a major incident: without proper command and control structures in place, the health service response will not work efficiently. Safety issues are clearly of great importance – one can be of no help to a patient if injured oneself.

The priorities of management at a major incident may be remembered by the mnemonic CSCATTT (Advanced Life Support Group, 2002):

- **Command & Control**
  - The cornerstone of management of the incident, this centres on establishing proper command structures, including establishment of the treatment areas (including a Casualty Clearing Station (CCS) where most health service resources will be based).
- **Safety**
  - Of oneself, the scene and then the survivors (the “1-2-3 of safety”).
- **Communications**
  - Both within and between emergency services at the scene, and to and from receiving hospitals.
- **Assessment**
  - A rapid needs assessment of the scene, from a health service point of view.
- **Triage**
  - Prioritising patients into (typically) immediate, urgent and delayed categories for treatment.



- Treatment
  - Life saving first aid at the scene, and advanced life support at the CCS.
- Transport
  - Of the most appropriate patient by the most appropriate means to the most appropriate facility.

The first stage of active patient management is triage, which only occurs after many other structures are put into place. Triage facilitates the aim of the management of the incident: to do the most for the most. Failure to appropriately triage will lead to valuable resources being diverted from patients who need them most, and compromise the overall incident response (Kennedy et al, 1996).

### **1-1-2: Triage**

In the initial stages of a major incident, medical and paramedical support at the scene will arrive in a staggered fashion over a period of time. Initially, it is unlikely that there will be sufficient numbers of trained staff to deal with all the casualties simultaneously. If the best care is to be given to the greatest number of casualties then a method of assigning priorities is necessary (Bissell et al, 1996). This method of assigning priorities is termed triage.

The term triage stems from the French verb “*trier*”, meaning *to sort*. It was originally used during the Napoleonic wars when, for the first time, priorities for treatment were based upon medical priorities rather than rank or status. Prior to this time, injured soldiers lay on the battlefield until the battle was over, at which point

they were collected in the order that they were found. Napoleon's surgeon, Baron Dominique Jean Larré, used triage to identify the least injured soldiers who could be quickly treated and then returned to the battlefield at the earliest opportunity (Larré, 1832).

Advances came slowly, with regiment surgeons opposing the triage proposals of John Morgan (director general of hospitals for the American Revolutionary Army) during the American Civil War (Flexner, 1969). Naval surgeons in 1846 recorded that lifesaving surgery could only be carried out on those most at need if treatment was withheld from those most likely to die from their injuries (Wilson, 1846). By the time of the Second World War, however, little progress had been made. Triage systems put in place in the Vietnam War helped to ensure that mortality rates dropped significantly (Eiseman, 1967).

Although originally developed for use in military conflicts, triage (albeit with strictly medical priorities rather than military ones) is equally applicable to civilian major incidents. It is a key component of medical support during a major incident (Advanced Life Support Group, 2002). It allows an unmanageable task to be divided into component parts.

Accurate triage allows correct identification of those patients who need the most urgent intervention, as well as identifying quickly and safely those who can wait longer for treatment (this group is the majority at a typical major incident (Carley and Mackway-Jones, 1996)). Triage may also be used to identify those patients who are so severely injured that they will not survive, or whose treatment will tie up resources that would be best used with other patients.

Triage is dynamic: as the patient's condition progresses, so their need for intervention alters and their triage category will change. In order to reflect this process, triage must be repeated regularly: it is only a snapshot of the patient's condition at that time. Typically, triage will occur at the following times through a major incident:

- At the scene (Primary triage)
- At the Casualty Clearing Station (Secondary triage)
- For transport to hospital
- At the hospital Emergency Department
- For transfer to intensive care or operating theatres
- For order of surgical intervention

This thesis is concerned with the triage that occurs prior to formal medical intervention: primary triage. This occurs as the triage officer picks his way through the scene of the incident, and identifies patients for urgency of medical intervention. As the triage officer may be faced by large numbers of casualties at this time, the system needs to be fast and easy to apply. Typically, a team would follow the triage officer and evacuate the patients to a dedicated treatment area – the CCS. At the front door of the CCS, there is a little more time to make triage decisions and so a more complex system is acceptable for this secondary triage.

### **1-1-2a: Triage Priorities**

Triage priority schemes vary across the globe, and within countries. UK military personnel use the T (Treatment) system, whilst NATO uses P (Priority).

Civilian organisations tend to use colour-coded priorities, although this is not universal. The only notable difference between the T and P systems is the use of the expectant category. Both the T and P systems can be (and are) used in conjunction with colour coding, as detailed in **table 1.1**.

Description	Colour	Priority system	Treatment system
Immediate	Red	P 1	T 1
Urgent	Yellow	P 2	T 2
Delayed	Green	P 3	T 3
Expectant	Blue		T 4
Dead	White	Dead	Dead

**Table 1.1: Major incident triage categories**

For the purposes of this thesis, the T system will be used. In the T system, patients are triaged as:

- **T1 (Red):** *Immediate*. Immediately life threatening problems, requiring immediate intervention. This may include patients with airway obstruction or severe breathing problems.
- **T2 (Yellow):** *Urgent*. Surgical or medical intervention is required within 2-4 hours. Such patients may include those with intra-abdominal bleeding.
- **T3 (Green):** *Delayed*. Less serious cases whose treatment can safely be delayed beyond 4 hours. Minor fractures or lacerations are likely to be seen in this group.
- **T4 (Blue):** *Expectant*. Patients whose condition is so severe that they are unlikely to survive despite the best available care, and whose treatment would

divert medical resources away from salvageable patients who may then be compromised. This group may include patients with extensive burns.

The T4 (expectant) category has never been instigated in civilian major incidents within the UK. It is more likely that this would be necessary in a military setting, where health care resources are even more limited. In practical terms, the decision to invoke the T4 (expectant) category rests with the Health Services Commander at the scene; it can be revoked later when more resources become available. If this occurs, these patients should become T1 (immediate). Avoiding using this category may be a mistake: it may cost lives. The other category, which is common to all systems, is Dead (White).

Whichever triage system is used, all health care resources at the scene must use it. Furthermore, the system must be easy to teach (so that inexperienced personnel can quickly adopt it and use it at the scene), fast to perform, and accurate (it must identify those patients who are seriously injured as well as those who are less serious) (Kennedy et al, 1996).

### **1-1-2b: Triage Systems**

There are numerous triage systems that exist for use on a day-to-day basis, both pre-hospital and in-hospital. A number of these have been modified to produce triage systems for use in major incidents (see **chapter 3**), where different systems are typically applied for primary and secondary triage. Primary triage is a very rapid “first look”, quickly categorising patients by simple discriminators. For example, in many systems the ability to walk leads to automatic triage as T3 (Delayed, or

Green). Secondary triage can be more in-depth, and systems may allow for an experienced triage officer (such as a senior doctor) to apply judgement or anatomical considerations to the priority determination. However, if the CCS becomes flooded by large numbers of casualties then reversion to the primary triage scheme is recommended.

The simplest and fastest systems tend to be based on easy to identify parameters that can be detected by personnel with any degree of training. Many systems rely on the presence of an open airway as a discriminator: in addition to such items, physiological parameters are typically used in primary and secondary triage schemes, as they are reproducible to measure and are not dependent upon operator experience. Such physiology generally involves respiratory rate (RR) and heart rate (HR), although capillary refill time (CRT) is occasionally advocated.

### **1-1-2c: Triage in Children**

As with adult triage, there are numerous triage systems available for prioritising children on a day-to-day basis, where patients are dealt with one at a time, and therefore the time taken to triage is not so crucial. These systems cannot be applied in major incidents.

There are specific concerns about the triage of children in major incidents (Holbrook, 1991): these have often been raised in major incident case reports (Vukmir and Paris, 1991; van Amerongen et al, 1993; Wass et al, 1994) and it is a commonly expressed concern on major incident management courses (Advanced Life Support Group, 2002). These concerns have been directed at the effectiveness of adult based triage tools to accurately triage children.

One such adult system that is applied to children is Careflight methodology, in use through many parts of Australia (Nocera and Garner, 1999). Like Careflight, most major incident triage systems are based on adult physiology. If these values are applied to small children then there will be an artificially high triage priority assigned. It has been argued that this is a useful thing to occur (so that children are removed from the scene at the earliest opportunity) (Nocera and Garner, 1999), or that it is appropriate as children are more likely than adults to survive head injury and multi-organ failure (Luerssen et al, 1988; Wilkinson et al, 1986). However, it is likely that paediatric resources (both at the scene and at hospital) will be limited and will risk becoming overwhelmed by inappropriately triaged children. This can lead to genuine cases not receiving the care that they require.

To overcome this problem, a child-specific major incident triage tool is needed. There are two specific paediatric primary triage tools in common use at present. JumpSTART (Romig, 2002), used throughout much of the United States of America (USA) is designed for children aged one to eight years (children older than eight years are triaged with START methodology (Super et al, 1994; Romig, 2002)).

The other algorithm (currently in use through much of the UK, many parts of Europe, parts of Australia, India and South Africa), is the Paediatric Triage Tape (PTT) (Hodgetts et al, 1998), a simple to use vinyl tape (see **chapter 3**). This tape is designed for children under 140cm in height (or up to 10 years of age).

However, there are still problems with tools such as these: to be rapid and easy to use, they measure simple physiological parameters. In children, these values vary related to age, height and weight. Triage systems therefore have to reflect these differences at different stages of growth. This makes any available triage tool

necessarily more complicated. Furthermore, the ranges of values of physiological parameters that we accept as normal in children of different ages may not be accurate, making currently available triage tools for children unreliable.

## **1-2: Physiological Reference Ranges in Children**

Whichever specific paediatric triage tool is used, there remains a problem with the physiological values on which that tool is based. Children's "normal" physiological values are more difficult to determine than those of adults, as they vary related to age, height and weight (often with a large spread for a given age). There is known to be an inverse relationship between body mass and RR in mammals (Heusner, 1983), and these data are usually extrapolated to apply to children for both respiratory and heart rate.

In order to derive clinically meaningful information for the paediatric patient, the vital signs recorded must be compared against a normal or reference range. There is good evidence for normal values of CRT (Bumke and Maconochie, 2001), although it varies with temperature of the environment (Schriger and Baraff, 1988), the patient's temperature (Gorelick et al, 1997) and his / her state of hydration (Schriger and Baraff, 1991). With regard to peripheral cutaneous oxygen saturations (referred to from now on as SaO<sub>2</sub>), there is also good evidence for "normal" values in health (Marcus et al, 1992; Mok et al, 1986). Systolic blood pressure varies with age, and although simple formulae to remember normal values have been suggested (such as  $80 + (\text{twice the age in years}) \text{ mmHg}$ ) (Advanced Life Support Group, 2005) the relationship with age appears more complex. There are ample data in support of reference ranges in health in childhood (de Swiet et al, 1992; Voors et al, 1982). It is



widely taught that blood pressure will fall or at least remain normal following injury in children (Advanced Life Support Group, 2005; American College of Surgeons, 2005), but a recent analysis of 9469 injured children on a UK database suggests that post-injury, children are moderately hypertensive (Dark et al, 2002). This may require health professionals to rethink their use of systolic blood pressure measurements post-injury in children.

With regard to RR and HR there is little evidence on which to base our “normal” values. Despite this, textbooks produce tables of reference values for various age groups. *Bates’ guide to physical examination and history taking* (Bickley and Hockleman, 1999) states that the normal values for RR in a newborn

“should be 30 - 60, reducing to 20 – 40 in early childhood and 15 – 25 in older children.”

The same book suggests that the normal HR for a newborn should be 140, reducing to 115 between six months and one year, 110 between one and two years, 103 between two and six, 95 aged six to 10, and 85 between 10 and 14 years.

Furthermore, courses such as the Advanced Trauma Life Support (ATLS) (American College of Surgeons, 2005) and Advanced Paediatric Life Support (APLS) (Advanced Life Support Group, 2005) didactically teach age related ranges of normal physiological values, but without an evidence base. The reference values given vary from one source to another: quoted values from popular texts are presented in **table 1.2**.

These values produce widely differing ranges of what may be termed normal for healthy children. In a one year old, for instance, the range of quoted RR values is

from 25 to 60: a rate of 30 would be considered normal in some of these texts, whilst others consider this bradypnoea and recommend intervention.

Text	Age	Heart rate	Respiratory rate
APLS (ALSG, 2005) <i>(range)</i>	<1	120-160	40-60
	1-2	110-150	30-50
	2-5	95-140	25-30
	5-12	80-120	20-25
	>12	60-100	15-20
ATLS (ACS, 2005) <i>(upper limit)</i>	BIRTH – 6/12	180-160	60
	INFANT	160	40
	PRESCHOOL	120	30
	ADOLESCENT	100	20
FORFAR(Campbell and Macintosh, 2003) <i>(range)</i>	NEWBORN	70-120	40
	INFANT	80-160	30
	PRESCHOOL	75-120	25
	SCHOOL	70-110	20
BATES (Bickley and Hockleman, 1999) <i>(upper limit)</i>	NEWBORN	140	30-60
	6/12-1	115	
	1-2	110	20-40
	2-6	103	20-40
	6-10	95	15-25
	10-04	85	15-25
NELSON (Bateman et al, 2003) <i>(mean)</i>	NEWBORN	125	
	1	120	20-30
	2	110	20-30
	4	100	20-25
	6	100	20-25
	8	90	14-22
	10	90	14-22
	12	85-90	12-18
	14	80-85	12-18
	16	75-80	12-18
18	70-75	12-18	

**Table 1.2: Age related heart and respiratory rate, various sources**

Furthermore, the majority of texts fail to provide any evidence to support the values that they quote. It is unlikely that these ranges are evidence based. This is clearly of concern for everyday clinical practice, where many judgements are made

on variations from this “normal” range of physiology in children. With regard to major incident triage, the concern relates to the use of incorrect physiological values to determine triage priority for a child. This may lead to overtriage, with the resultant inappropriate use of limited paediatric resources, or undertriage, where a seriously injured child is overlooked.

Before a physiologically based paediatric triage tool can be properly assessed, therefore, it is important to establish the correct reference ranges for HR and RR.

### **1-3: Standards Against Which to Validate Triage Tools**

No matter which conditions specific triage tools have been designed to be used in (day-to-day identification of individual patients for trauma centre care, or major incidents), they must be validated by testing their ability to correctly identify those patients who require immediate medical intervention, as well as those patients who are less serious. How this validation occurs is problematic.

The currently accepted gold standard against which tools are tested is the Injury Severity Score (ISS) (Baker et al, 1974) (see **chapter 5**). The ISS is based upon a series of scores for particular injuries, all of which are consensus based. It is designed to identify seriously injured patients (those with an ISS of 16 or above) for trauma centre care. However, it makes no attempt to discriminate between those patients who have an ISS less than 16 in terms of their seriousness or urgency for medical attention. Some authors think that the New Injury Severity Score (NISS) (Osler et al, 1997) is a better indicator of severity of injury than ISS (Lavoie et al, 2004), although this opinion has yet to gain wide acceptance.

Baxt and Upenieks challenged the use of the ISS in validating triage tools. They showed that the ISS missed a significant number of seriously injured patients, who can be identified by the intervention that they require rather than the specific injury that they sustain (Baxt and Upenieks, 1990). They suggested a series of criteria against which a triage tool could be tested (**table 1.3**). This series was later modified by Garner *et al* to be applicable to major incidents (Garner et al, 2001) (**table 1.4**). This is a resource-requirement based outcome tool, more appropriate than the ISS for the study of major incident triage.

<b>Intervention</b>	<b>Description</b>
Operative intervention	(Non-orthopaedic; within 48 hours)
Aggressive fluid resuscitation	(More than 1000ml)
Invasive central nervous system monitoring	(Or a positive head Computerised Tomogram)

**Table 1.3: Baxt and Upenieks criteria**

<b>Intervention</b>	<b>Description</b>
Operative intervention	(Non-orthopaedic; within 6 hours)
Fluid resuscitation	(1000ml or more)
Invasive CNS monitoring	(Or a positive head CT scan)
A procedure to maintain the airway	(Or assisted ventilation)
Decompression of a tension pneumothorax	

**Table 1.4: Garner criteria**

The use of consensus expert opinion to derive criteria against which a triage tool can be tested has been established by the appearance of these two articles in

international, peer reviewed journals. Such a method is preferable to the use of the ISS as it allows for correct identification of casualties based upon medical need, rather than on specific injury severities alone. This method can be applied in the validation of specific triage tools, including the PTT, and can be developed further with the derivation of expert opinion based outcome criteria.

#### **1-4: Choice of Location for Validation of the Paediatric Triage Tape**

In order to test the ability of the PTT to triage children, a large volume of injured children need to be studied. In the UK, no one hospital sees enough seriously injured children on an annual basis to provide this sort of data. A UK wide trauma database, the Trauma Audit Research Network (TARN) has developed a new database for children only (TARNLET), which currently contains around 26,000 children (*personal communication, TARN, Manchester*). However, the database only contains children who are admitted to hospital or die from their injuries, hence excluding children with minor injuries. Furthermore, their presenting physiological data are not uniformly recorded and these data, therefore, are not suitable to test tools like the PTT. A setting needed to be chosen where large numbers of injured children are regularly seen, in which the PTT could be prospectively validated.

South Africa was considered as a location for validation of the PTT. Of 44 million people currently living in South Africa, 15 million are aged under 15 years (Statistics South Africa, 2003). The National Burden of Disease study (Bradshaw et al, 2003) found 114,000 deaths in children aged under 15 years in 2000. Of these, almost half were related to Human Immunodeficiency Virus (HIV) infection, but up to 10% were trauma related. For each death, there are up to 10 seriously injured

children (personal communication, *Prof AB Van As, Cape Town*). There is clearly a major problem with childhood trauma in South Africa.

The Red Cross War Memorial Children's Hospital (RXH) opened in Cape Town after the Second World War: returning servicemen who had served in the war funded its construction (in place of a war memorial for their fallen comrades). Although a state run hospital (and therefore often short of funds and equipment), RXH is now widely regarded throughout the world as a centre of excellence for paediatric care. Because of this, it attracts significant amounts of charitable monies each year, and also is a locus for overseas doctors who wish to gain some in depth paediatric experience. It is Africa's only dedicated children's hospital south of Cairo.

The hospital serves a local population of three million (of whom almost 40% are under 15 years of age (Statistics South Africa, 2003)), and has 230 beds. Twenty of these beds are on the admissions ward in the Trauma Unit and 26 in Intensive Care. The Trauma Unit is run by paediatric surgeons, and currently sees between 8000 – 10000 patients per year. Day-to-day staffing is provided by surgical registrars, who can call on all in-patient specialities for assistance. The case mix in the Trauma Unit varies, but is predominantly from Motor Vehicle Accidents (MVAs) or falls. During winter the unit sees a considerable number of burn cases. The unit admits a mean of 220 patients per month, of whom approximately 25% need surgery. A further ten (mean) patients are admitted to ICU each month from the Trauma Unit, and there are three (mean) deaths in the unit each month.

The case mix and injury severity makes the RXH Trauma Unit the most appropriate location in which to validate the PTT.

## **1-5: Aim**

The aim of this thesis is to validate the Paediatric Triage Tape for use as a primary triage tool in major incidents. To achieve this, there are three key objectives.

The PTT was designed in the United Kingdom, and is physiologically based. As the validation is taking place in South Africa, it is necessary to compare physiological values in children in the UK with those in South Africa. The first objective of this thesis, therefore, is to establish reference ranges of heart rate and respiratory rate in the UK, and compare these to reference ranges in South Africa.

The second objective of this thesis is to derive a more appropriate outcome measure against which to test the PTT (and other major incident triage tools). This outcome measure will be used as part of the validation process for the PTT. However, as general consensus is still that Injury Severity Score and related measures are the best current “gold standards”, validation will also be undertaken against these measures.

If there is no difference in the physiological ranges between the two countries, the validation can proceed in South Africa with no adjustments required. However, if there is a difference then data recorded as part of the PTT validation will need to be adjusted to be applicable to the UK derived triage tool. The development of a prospective database and testing the PTT against these data to establish its accuracy is the final objective of this thesis.

## 1-6: Summary

- The health service management of a major incident does not depend solely on treating patients. Command structures are the key to establishing proper control of the scene before the first patient is dealt with. Once these structures are established, the most effective use of health resources depends upon appropriate triage of the casualties.
- Inappropriate triage results in misuse of resources or missed patients. Triage systems for use in major incidents need to be simple to use, rapid and accurate. The ideal system does not exist at present.
- When triaging children at major incidents, adult-physiology based systems will mis-prioritise. Physiologically based triage tools need to use children's ranges of values, which vary with age. However, the currently accepted ranges of normal values for such parameters vary widely and may not be evidence based.
- Testing triage tools to determine whether they accurately identify different degrees of priority in patients is difficult and flawed: expert consensus derived criteria may be appropriate to develop a system against which a tool can be tested.
- One such triage tool designed for paediatric triage at a major incident is the Paediatric Triage Tape. It is physiologically based, but has not been validated. It was tested for this thesis in the Red Cross War Memorial Children's Hospital, Cape Town.



**CHAPTER 2:**  
**LITERATURE REVIEW**

An extensive literature search was undertaken at the beginning of the research period (2001), and was repeated at regular intervals throughout the intervening period until completion of the thesis. The last search was in June 2005.

Searching was completed using a combination of electronic medical databases, general electronic search engines, and medical library information. Search terms varied for different sections of the thesis, falling mainly into physiological articles, those relating to triage and those relating to Delphi methodology.

Electronic medical databases searched include:

- Pre-Medline
- Medline (1966 – present)
- Embase (1974 – present)
- Cinahl
- British Nursing Index
- Cochrane library (all databases)

All retrieved records were assessed for relevancy.

The Google® search engine was searched using more general terms.

Hand searching of the following journals was undertaken at the University of Cape Town medical library:

- The Lancet 1990 – 2005
- British Medical Journal 1990 – 2005
- Archives of Disease in Childhood 1990 - 2005

- Pediatrics 1990 - 2005
- Journal of Pediatric Surgery 1994 - 2005
- Acta Paeditica 1990 - 2005

Attempts were made to identify relevant articles in the grey literature, through sources including:

- The System for Information on Grey Literature in Europe
- The National Technical Information Service (NTIS) Federal Research in Progress database
- Dissertation abstracts

Conference proceedings were searched where possible, through databases including:

- ISI web of science index of scientific and technical proceedings
- Conference papers index
- British library online catalogue

The National Research Register was also analysed.

The bibliographies of all papers retrieved were analysed for any other relevant articles.

All relevant English language articles were retrieved.

## CHAPTER 3:

### BACKGROUND – PRE-HOSPITAL TRIAGE

- 3-1 Introduction
- 3-2 The Development of Pre-Hospital Triage Methods
- 3-3 Methods of Triage
  - 3-3-1 Mechanism of Injury
  - 3-3-2 Demographic Information
  - 3-3-3 Anatomical Derangement
  - 3-3-4 Physiological Derangement
- 3-4 Triage at Major Incidents
  - 3-4-1 Triage Tools
  - 3-4-2 Primary Triage
    - 3-4-2a Triage Sieve
    - 3-4-2b Careflight
    - 3-4-2c START
- 3-5 Major Incident Triage of the Injured Child
  - 3-5-1 The Paediatric Trauma Score
  - 3-5-2 The Trauma Score and the Triage Revised Trauma Score
  - 3-5-3 Paediatric Primary Triage Tools
    - 3-5-3a The Paediatric Triage Tape
    - 3-5-3b Jumpstart
- 3-6 Summary

### **3-1: Introduction**

This chapter considers the methods and aims of triage in major incidents, with reference to the difficulties of triaging children in the pre-hospital environment. It looks at the development of pre-hospital triage methodologies and their applicability to major incidents. This chapter discusses the evidence relating to specific paediatric scoring systems and how these may be used in a major incident setting.

This chapter attempts to answer the specific question of what is the best method of triaging children in a major incident.

### **3-2: The Development of Pre-Hospital Triage Methods**

Systems of pre-hospital triage have been developed predominantly in the USA, where a regionalised system of trauma care exists in many states. Scores have been devised predominantly to identify trauma patients who need to go to trauma centres - specialist units that deal with a high trauma workload. There has been little attempt to develop triage tools for medical patients.

Attempts to develop trauma triage tools began in the 1970s with empiric criteria being used (Kirkpatrick and Youmans, 1971; Ogawa and Sugimoto, 1974; Bever and Veenker, 1979). These tools were not scientifically derived and had poor predictive abilities (Baxt et al, 1989). Champion adopted a more robust approach through regression analysis of a trauma database, to produce the Triage Index (Champion et al, 1980) – the first physiologically based tool derived by such means. Many methods have been devised since then, and some of the commoner tools along with their measured parameters are shown in **Table 3.1**.

	Anatomical Injury	Mechanism of Injury	Demographic Information	Physiological Parameters
Triage-Revised Trauma Score (Champion et al, 1989)				Y
Trauma Score (Champion et al, 1981)				Y
CRAMS (Gormican, 1982)	Y			Y
Paediatric Trauma Score (Tepas et al, 1987)	Y	Y	Y	Y
ACS Trauma Triage criteria (Henry et al, 1996a)	Y	Y		Y
Revised Trauma Index (Smith and Bartholomew, 1990)	Y	Y		Y
Revised triage checklist (Kane et al, 1985)	Y	Y	Y	Y
Revised triage scale (Kane et al, 1985)	Y	Y		Y
Triage Checklist (Kane et al, 1985)	Y	Y	Y	Y
Triage Scale (Kane et al, 1985)	Y	Y		Y
Pre-hospital Index (Koehler et al, 1986)				Y

**Table 3.1: Pre-hospital triage methods**

Many of the algorithms in use have been designed to be “failsafe” - that is, they deliberately overtriage patients to trauma centres thus ensuring that they miss (undertriage) very few patients (Knudson et al, 1988). This reduces mortality

(Kilberg et al, 1988), but at the cost of many unnecessary referrals (O'Rourke et al, 1992; Baxt et al, 1989) (however, in major incidents overtriage may be dangerous: Frykberg showed a clear relationship between the rate of overtriage and mortality (Frykberg, 2002)).

These scores have been developed to identify those patients who would benefit from trauma centre care. In trauma centre triage, scores are selected to be very sensitive at identifying patients with an ISS of 16 or higher (16+), those needing emergency surgery or those who subsequently die (Champion et al, 1981; Champion et al, 1989; Baxt et al, 1989; Koehler et al, 1987; Koehler et al, 1986; Henry et al, 1996a; Kane et al, 1985; Smith and Bartholomew, 1990; Meredith et al, 1995; Lyle et al, 1990; Knopp et al, 1988; Gormican, 1982; Baxt et al, 1990; Tepas et al, 1987; American College of Surgeons, 1998; West et al, 1986; Long et al, 1986; Knudson et al, 1988; Kreis et al, 1988; Newgard et al, 2002). This selectivity may not be entirely appropriate for non-regionalised health care systems, such as that provided in the UK. However, the majority of pre-hospital triage systems have been developed and tested in the USA, with subsequent adoption in other countries.

When testing a triage system, one may consider the:

- Sensitivity
- Specificity
- Positive predictive value (PPV)
- Negative predictive value (NPV)
- Undertriage rate
- Overtriage rate

There are no definitive guidelines for the definition or calculation of these parameters. Sensitivity and specificity are calculated as is standard using a two by two table: overtriage and undertriage may be defined in two ways (see below). Scores with a significant undertriage rate do not identify all those patients with serious injury. Scores having a high overtriage rate erroneously identify patients with minor injuries as high priority. Several authors have shown that undertriage is inextricably linked with overtriage: as one decreases, the other increases (Cottingham et al, 1988; West et al, 1986; Kane et al, 1985).

The Committee on Trauma of the American College of Surgeons (ACSCOT) has attempted to describe what over- and undertriage mean in a practical sense, and they define:

“...over-triage, as minimally injured patients are transferred to trauma centres, and under-triage, as severely injured patients are taken to non-trauma centres. In general, priority has to be given to reduction of under-triage, because under-triage may result in preventable morbidity or mortality.....” (American College of Surgeons, 1998).

They further state that:

“....an under-triage rate of 5 to 10 percent is unavoidable, and is associated with an over-triage rate of 30 to 50%. An over-triage rate of up to 50% may be required to maintain an acceptable level of under-triage....”.

Newgard *et al* (Newgard et al, 2002) calculated undertriage as (1-specificity) and overtriage as (1-sensitivity): however, this is not uniformly accepted, does not correspond with the definition by ACSCOT, and none of the values quoted even approach those termed acceptable by ACSCOT.



Although there is no guidance as to the definition of positive and negative predictive values, Cottington *et al* (Cottington et al, 1988) used these values as the basis for their calculation of over- and undertriage. They calculated overtriage as 100 minus PPV, and undertriage as 100 minus NPV. In the absence of strict definitions, a degree of judgement and common sense is required. For this thesis, the definitions of Cottington *et al* have been used (see below).

The two-by-two table at **table 3.2** is used to help define these parameters, with regard to identification of T1 (immediate priority) patients.

		Tool identifies as		
		Priority 1	Not priority 1	
Patient should be	Priority 1	A	B	A+B
	Not priority 1	C	D	C+D
		A+C	B+D	A+B+C+D

**Table 3.2: Two by two table**

**Sensitivity** is the ability of the score to identify seriously injured patients: that proportion of all T1 patients which the tool identifies as T1.

$$A/A+B$$

**Specificity** is the ability of the tool to identify patients who are not seriously injured: that proportion of not-T1 patients who are correctly identified as not-T1 by the tool.

$$D/C+D$$

**Positive predictive value** describes the proportion of those patients labelled by the tool as T1, who actually are T1.

$A/A+C$

*Negative predictive value* describes the proportion of those patients that the tool labels as not-T1 who are actually not-T1.

$D/B+D$

Undertriage and overtriage may be defined differently. *Undertriage* may be considered to be either:

Those patients who are triaged as not-T1 by the tool, but who are really T1 (1-NPV).

$B/B+D$

(Alternatively, those patients who are not identified as T1 but who should really be T1 ( $B/A+B$ ) may be used (1-specificity)).

Similarly, *Overtriage* may be described as:

Those patients who are triaged T1 by the tool but are really not-T1 (1-PPV).

$C/A+C$

(Alternatively, those patients who are not T1 who were identified by the tool as being T1 ( $C/C+D$ ) may be used (1-sensitivity)).

The former definitions of undertriage and overtriage (as used by Cottington *et al* (Cottington et al, 1988)) will be used here: they reflect better the populations that they are intended to describe.

These definitions as described have only been published with reference to categorisation as T1 / not T1. However, they are equally valid for T2 / not T2 patients. For T3 / not T3 the definitions of undertriage and overtriage remain the same but they should be calculated in the “opposite direction”, hence:

$$\textit{Undertriage} = C/A+C$$

$$\textit{Overtriage} = B/B+D$$

Although much research has been conducted there is as yet no score that is both highly specific and sensitive (Baxt et al, 1989). As sensitivity increases then specificity correspondingly decreases (Baker et al, 1974) and a balance must therefore be achieved depending upon the type of situation in which the triage score is to be used. Scoring systems used for trauma centre triage accept that they will overtriage many patients to a trauma centre who would not necessarily benefit from the specialist facilities there, presuming that it is essential that all casualties with a potentially serious injury are transported to the trauma centre (Kane et al, 1985; Smith and Bartholomew, 1990; American College of Surgeons, 1998; Cales, 1985). Although overtriaging patients to trauma centres reduces mortality, many referrals are unnecessary as patients often have minor injuries (Meredith et al, 2002; Meredith et al, 1995; Kreis et al, 1988).

Paradoxically, in major incidents such caution may be detrimental to the overall incident response. If a score overtriages to such an extent that the majority of casualties are identified as in need of more urgent care then patients with minor injuries may be directed to the resuscitation teams thereby delaying care for the most

seriously injured. In major incidents a lower degree of overtriage is therefore essential.

### **3-3: Methods of Triage**

Many different criteria are used to assign priorities in pre-hospital triage. Scores generally use one or all of the following different methods:

- Mechanism of Injury
- Demographic Information
- Anatomical Derangement
- Physiological Derangement

#### **3-3-1: Mechanism of Injury**

Mechanism of injury scores make assumptions about the likely severity of injury based upon the force transferred in the injury. They include variables such as falling over 15 feet, involvement in a motorcycle crash, or pedestrian knocked over by a motor car (Kane et al, 1985; Jones and Champion, 1989; Cook et al, 2001). Such tools have been shown to be highly sensitive at identifying casualties with severe trauma (Champion et al, 1980; Kane et al, 1985). This is a useful attribute, but must be weighed against the fact that they have also been shown to have high rates of overtriage (Baxt et al, 1989; Lyle et al, 1990; Knopp et al, 1988; West et al, 1986; Long et al, 1986; Kreis et al, 1988; Esposito et al, 1995). Newgard *et al* (Newgard et al, 2002) derived a paediatric triage tool from a database of almost 8500 children. This was based upon mechanism of injury in motor vehicle crashes (using passenger space intrusion and whether the patient was unrestrained as two out of three decision steps in the algorithm) and conscious level (GCS). The tool showed high sensitivity

(92%) and reasonable specificity (73%) at predicting patients with ISS >15, but the study failed to report overtriage and undertriage rates. However, only 0.6% of the dataset (47 children) had an ISS of 16 or higher, and of more concern, the dataset only contained GCS information on 14% (the missing 86% were assumed to have a GCS of 15). Data were present on all three variables in less than 10% - hence the actual derivation set was less than 1000 children, significantly reducing the reliability of the conclusions. This was further impacted as the data were only relevant to motor vehicle crashes anyway.

In major incidents, most (if not all) casualties are likely to have the same mechanism of injury, reducing the discriminatory value of this type of assessment to a bare minimum. For this reason mechanism of injury scores are not useful in major incident triage.

### **3-3-2: Demographic Information**

This is typically confined to a consideration of age. In some triage methods young children (Kane et al, 1985; Champion et al, 1981) and the elderly (Kane et al, 1985; West et al, 1983) are sent to trauma centres on the basis of age alone. This is because patients at the extremes of age may be difficult to assess in the field; furthermore, the elderly often have coexistent morbidity which is a strong independent factor on outcome (Milzman et al, 1992), while children are a diverse group with different physiology and anatomy (see **Chapter 6**). In incidents involving large numbers of the elderly or children, scores making such blanket judgements may adversely affect the overall response by overtriaging many patients. Children may already receive priority treatment and transport due to the emotional response they

create in their rescuers: further bias through systematic overtriage would compound this. Although the Paediatric Trauma Score (PTS) has been developed specifically for children (Tepas et al, 1987) it is relatively complicated to perform, has a significant rate of overtriage in the very young (Nayduch et al, 1991) and has few advantages over other adult-based scores (Eichelberger et al, 1989; Kaufmann et al, 1990). The PTS is considered in detail later in this chapter, but is not felt to be appropriate as a major incident primary triage tool.

### **3-3-3: Anatomical Derangement**

Anatomical description of injury has been shown to be a useful predictor of survival, and the use of the ISS is well established as the gold standard in systems of trauma scoring and audit. Other anatomical scores such as the Anatomical Profile (Copes et al, 1990) have more recently been developed. All anatomical scores are based on data acquired retrospectively from clinical examination, radiological imaging, operation and autopsy, and are therefore unsuitable for use in the major incidents (as such detailed information is unobtainable in the pre-hospital environment). Some trauma scores such as the PTS and the CRAMS scale (Gormican, 1982) use simple anatomical data (such as the presence or absence of fractures on clinical examination) as independent predictors of overall injury severity. Although a limited examination in the field may be possible for one or two casualties, the time taken to examine for anatomical injuries means that scores using anatomical information are unsuitable for use in major incidents (MacMahon, 1985).

### 3-3-4: Physiological Derangement

Measurement of physiological values has been shown to correlate well with the severity of injury or illness, and is considered by some to be a key component of any triage process - particularly for children and the elderly (Cooper et al, 2002). Such tools have been shown to be simple, safe, rapid to perform and reproducible between operators (Hodgetts, 1997).

Physiologically based triage score use variables based upon cardiovascular, respiratory or central nervous system function (**table 3.1**). Some scores rely on the measurement of CRT, but its variation with temperature (Schriger and Baraff, 1988) and difficulty in reading in low light conditions (Brown et al, 1994) limits its usefulness.

The measurement of physiological parameters illustrates how and to what degree the anatomical injuries have affected the casualty: they can therefore identify priorities for treatment without the need to search for occult injuries. If a child is injured but suffers no change in physiology, he will be afforded less priority than a second child who is physiologically deranged as a result of his injury. The degree of change from the physiological norm is also an indicator of the severity of injury, and this derangement is determined both by the type of injury and the time elapsed between injury and assessment.

Physiological scores may be used dynamically (repeated at regular intervals) to observe for a change in the measured values. A casualty's priority may therefore change with time or following clinical intervention. This important ability to change priority (Martin, 1993; Vayer et al, 1986) is exclusive to physiological assessment.

### **3-4: Triage at Major Incidents**

Triage methods used for the assessment of a single casualty are not necessarily applicable to the assessment of many casualties. In the assessment of a single patient, sufficient time may be available for a detailed history and physical examination. If many casualties require rapid assessment then methods of triage that take time or special equipment are of little value, as the time taken to assess a single casualty may delay and prejudice the care of other victims. It is desirable and commonly accepted to triage major incident casualties into the groups shown in **table 1.1** (Jacobs et al, 1979).

#### **3-4-1: Major Incident Triage Tools**

It is often argued that the use of objective scoring systems in the pre-hospital environment is unnecessary and that the use of paramedic or emergency physician judgement is superior to (or as good as) objective triage scores (Emerman et al, 1991; Coats et al, 1993; Champion et al, 1988; Simmons et al, 1995; Fries et al, 1994) (although this has not been shown to be the case for paediatric patients (Oazi et al, 1998)). However, this predictive ability has only been investigated in studies examining the triage of single casualties, which is clearly not the case in major incidents. Furthermore, these studies have relied on the presence of an experienced operator to undertake the triage, whilst many now recommend that a junior (or non-medical) person undertake primary triage, retaining valuable medical resources for where they can make more impact (Advanced Life Support Groups, 2002). Other studies of single casualty triage have found conflicting results, suggesting that such triage is highly subjective with poor interrater reliability, and is not useful at



identifying those patients who will be admitted to hospital (Gill et al, 1996; O'Brien et al, 1997; Brillman et al, 1996; Brillman et al, 1997).

Studies on pre-hospital triage for single casualties generally examine the ability of staff to use scores with which they are familiar on a day-to-day basis. Until pre-hospital care services in the UK adopt routine pre-hospital triage, extrapolating the results of these studies to UK practice is difficult. Where pre-hospital triage scores are in routine use, it may be beneficial to adjust the familiar score rather than institute a new score (Martin, 1993; Emerman et al, 1991): any benefits from a new score may be negated by the fact that the operators are unfamiliar with its use. As few UK pre-hospital care services routinely use any type of formalised triage score, this is unlikely to be of concern at present. Major incident triage in the UK will usually be performed by personnel who have never performed formal triage before. An objective, simple and quick method of assigning priorities is therefore required.

Objective methods have the advantage that they are reproducible, require little in the way of clinical skills or experience, and can be quickly and reliably taught to personnel with minimal medical training (MacMahon, 1985). For experienced clinicians, any additional information may be used with an objective scoring system to reach a final triage categorisation (Coats et al, 1993; Champion et al, 1988; Simmons et al, 1995).

As compared to trauma centre triage, the outcome measures required of a triage score at a major incident are different and should reflect the need for clinical intervention in a given patient rather than their future prognosis or resource requirements (Pepe and Kvetan, 1991). Major incident triage is designed to indicate a

patient's priority for clinical and resuscitative intervention. This does not necessarily correlate well with the degree of anatomical injury (Baxt and Upenieks, 1990).

Physiological assessment is the only method that equates to these outcome measures, and for practical reasons offers many advantages over anatomical, demographic or mechanism of injury based scores. The Trauma Score (TS) (Champion et al, 1981), Triage Revised Trauma Score (TRTS) (Champion et al, 1989) and the Pre-hospital Index (Koehler et al, 1986) are the only scores based solely on physiological assessment (**table 3.1**). The TS has been superseded by the TRTS, which is less complicated to perform in the pre-hospital environment and easier to calculate (Champion et al, 1989). The Pre-hospital index requires the calculation of four rather than three parameters and has shown to have a low specificity for major trauma (Ramenofsky et al, 1988): it requires subjective rather than objective assessment of physiological parameters and is therefore less suitable as a major incident score than the TRTS.

If any scoring system is to be of use in the major incident pre-hospital environment then it must be quick and simple to use, and require no specialist equipment. Speed and simplicity are essential, as a rapid assessment of many casualties may be necessary. The availability of specialist equipment cannot be guaranteed and therefore scores should rely on the measurement of clinical parameters. If equipment is to be used, it should be easily portable, robust and widely available. For primary triage, none of the pre-hospital triage tools in common use fulfil these requirements. However, both the TRTS and Secondary Assessment of Victim Endpoint (SAVE) are recommended as secondary triage tools in major incidents (Advanced Life Support Group, 2002; Benson et al, 1996).

At present there is no easy way to validate a major incident score, as experiment is not possible and there is no sufficiently robust method of computer modelling major incident outcome priorities. A degree of judgement must therefore be used in both the selection and use of a triage system.

The requirements of a triage score for a major incident are that it is (Kennedy et al., 1996):

- Quick (ideally taking no more than 15 – 30 seconds per casualty)
- Reproducible
- Easy to use (in the environment in which it is to be used)
- Able to describe major incident outcomes
- Dynamic

### **3-4-1: Primary Triage**

The method used for primary triage must fulfil all of the criteria above: it is paramount, however, that it is performed quickly and easily as this method will be used at the scene of the incident. Specific major incident primary triage tools have been developed in several countries for general use. They include:

- Triage Sieve (Advanced Life Support Group, 2002): UK and NATO, Sweden, Holland, part of Australia
- Careflight (Nocera and Garner, 1999): parts of Australia
- START (Super et al, 1994): USA

In 2003, Garner *et al* compared these three triage tools in their ability to identify patients with certain criteria following trauma in adults: the Careflight

algorithm was the most predictive in these circumstances (Garner et al, 2001). They also found that the ability to obey commands (the motor component of the GCS) was the strongest predictor of serious injury.

### 3-4-2a: Triage Sieve

The Triage Sieve was developed by the Advanced Life Support Group in Manchester. Its use in primary triage is combined with the use of the TRTS and experienced operator discretion as secondary triage (Advanced Life Support Group, 2002). It is illustrated at **figure 3.1** and **table 3.3**.

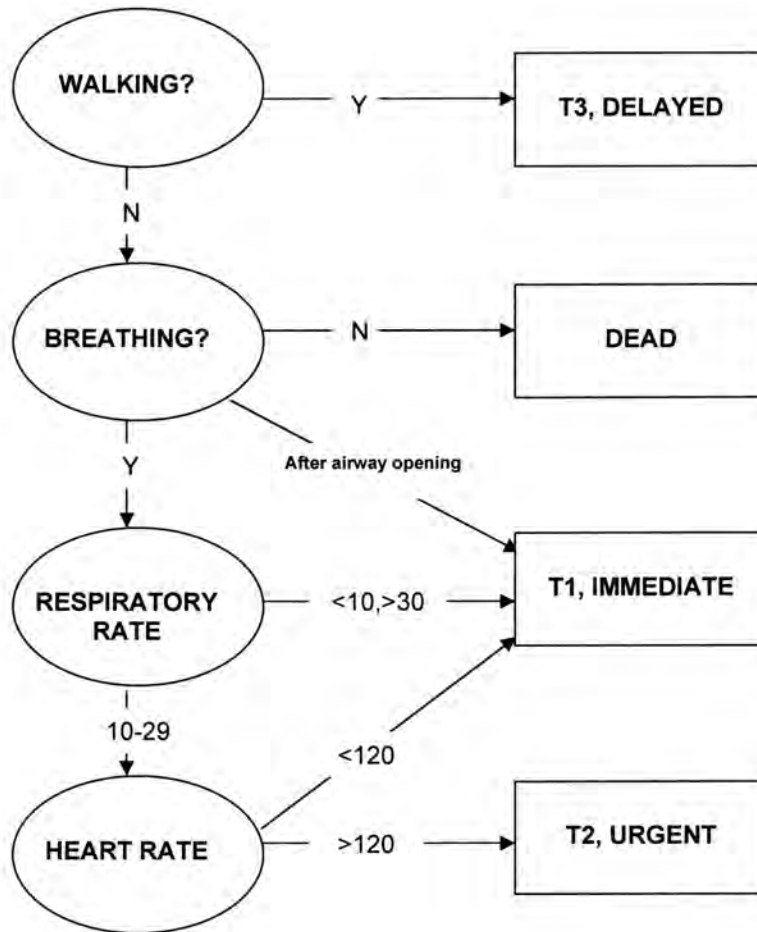
<b>Evaluation</b>	<b>Triage category</b>
Walking	<b>T3</b>
Not breathing with an open airway	<b>Dead</b>
Respiratory rate <10 or >29 per minute	<b>T1</b>
Heart rate < 120	<b>T2</b>
Heart rate > 120	<b>T1</b>

**Table 3.3: The Triage Sieve decision process**

The Sieve begins with an assessment of mobility – the ability to walk leads to classification as T3. If the casualty is unable to walk, an assessment is made of their airway. The absence of breathing with simple airway opening manoeuvres leads to the classification of the casualty as Dead. If the airway-opening manoeuvre is successful, the patient is T1.

If the patient has a patent airway, the RR is recorded over 15 seconds (then multiplied by four): a value under 10 or over 29 leads to classification as T1.

Otherwise, the HR is recorded: a value of over 120 means the patient is T1; a value below 120 leads to classification as T2.



**Figure 3.1: Triage Sieve**

The CRT may be used as an alternative to heart rate, although there are limitations on its use (it is unsuitable in the cold, dark, or if the rescuer is unable to access a central body area). If it is used, the value to distinguish between T1 and T2 is above / below two seconds.

### 3-4-2b: Careflight

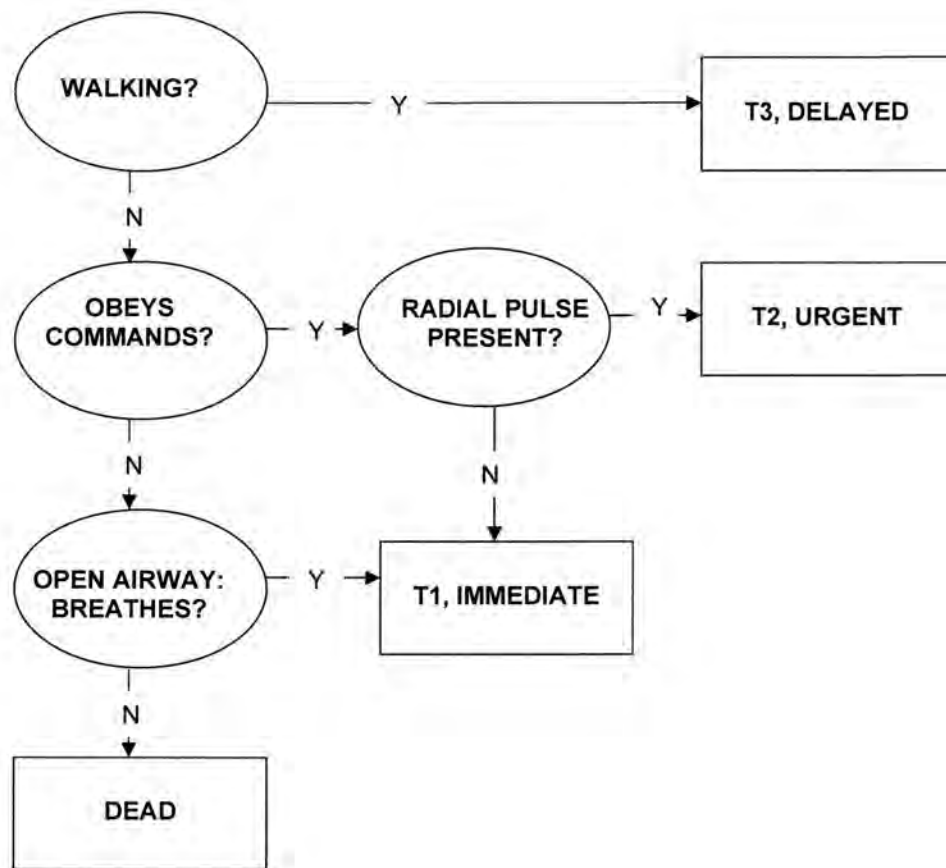
The use of Careflight as a primary triage tool is recommended in parts of Australia. It was developed as the Homebush triage standard for CareFlight New South Wales Medical Retrieval Services in Australia. CareFlight triage is based on a slightly modified version of the START algorithm (Super et al, 1994). There are no recommendations as to a suitable secondary triage tool to use with this algorithm. The Careflight triage scheme is illustrated at **figure 3.2** and **table 3.4**.

Walking	Obey commands	Palpable radial pulse	Breathes with open airway	Triage category
Yes				<b>T3</b>
No	Yes	Yes		<b>T2</b>
No	Yes	No		<b>T1</b>
No	Yes		Yes	<b>T1</b>
No	No		No	<b>Dead</b>

**Table 3.4: The Careflight decision process**

Careflight also begins with a simple assessment of mobility: the ability to walk means the casualty is T3. If they are unable to walk, the ability to obey commands is assessed. If the casualty can obey a simple command the radial pulse is palpated. If a radial pulse is absent the patient is T1: if present, they are T2.

If the patient cannot obey commands, the airway is opened. The presence of breathing means the patient is T1: otherwise, they are Dead.



**Figure 3.2: Careflight triage**

### 3-4-2c: START

The use of START triage is complemented at secondary triage level by SAVE (Benson et al, 1996). START triage is illustrated at **figure 3.3** and **table 3.5**, although the original algorithm used CRT rather than radial pulse (later modified (Benson et al, 1996)).

Again, the first assessment is that of the ability to walk. Mobile patients are classified as T3. If the patient is unable to walk and is not breathing despite airway opening manoeuvres, they are Dead.

<b>Evaluation</b>	<b>Triage category</b>
Walking	<b>T3</b>
Not breathing with simple airway manoeuvres	<b>Dead</b>
Cannot walk AND can obey commands AND radial pulse present AND respiratory rate < 30	<b>T2</b>
Anyone else	<b>T1</b>

**Table 3.5: The START decision process**

If the patient is able to breathe, but has a RR of 30 or higher, they are T1. If the breathing rate is under 30 the presence of a radial pulse is sought: the absence of a pulse leads to categorisation as T1. If a pulse is present the ability to follow commands is assessed – the inability to do so means the patient is T1: otherwise they are T2.



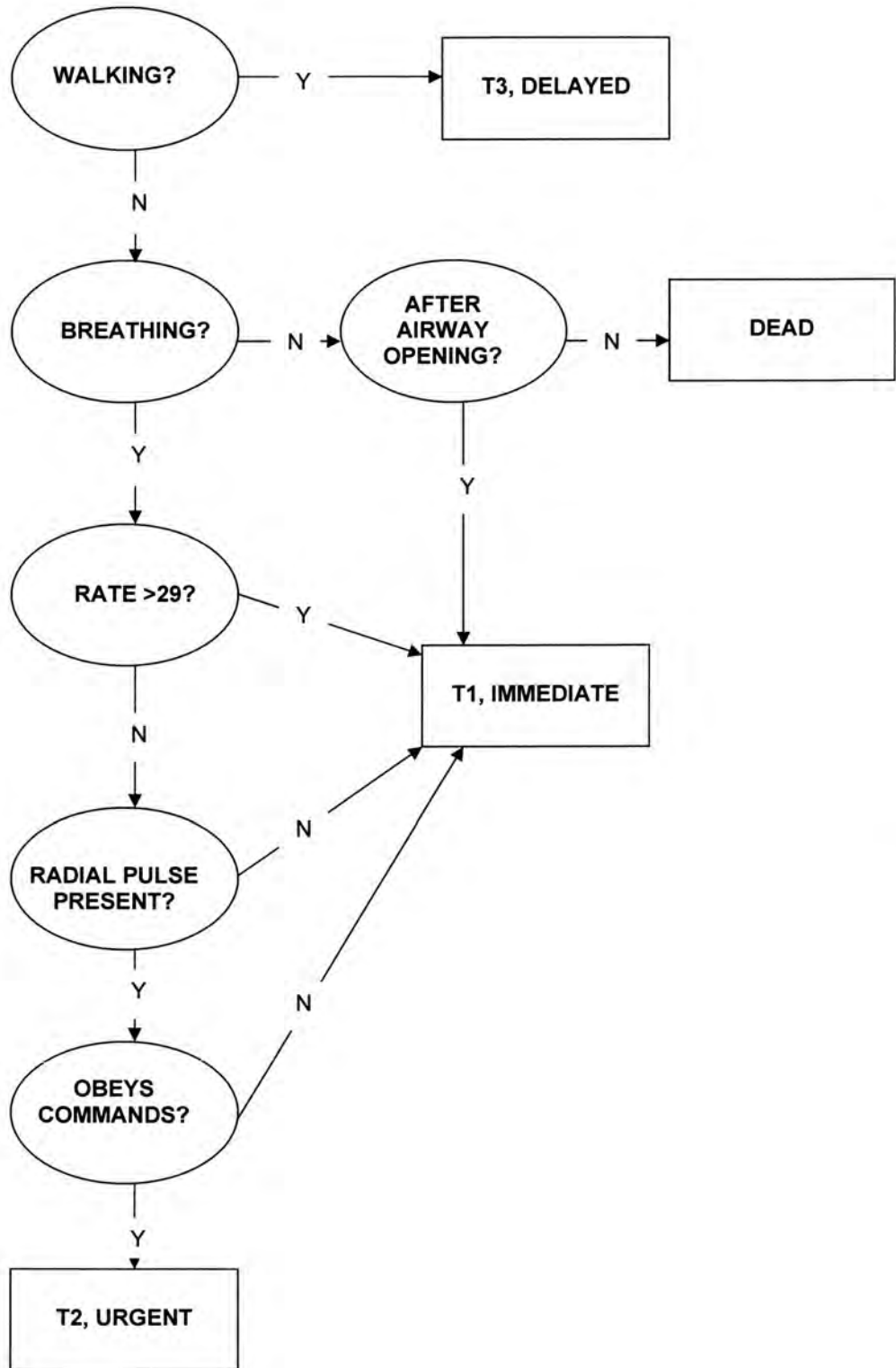


Figure 3.3: START triage

### **3-5: Major Incident Triage of the Injured Child**

Triage in children is complicated by the fact that anatomically, physiologically and psychologically they are different to adults and are themselves a heterogeneous group. As with adult major incident triage there are potential benefits to using day-to-day triage methods as major incident scores because operators will be familiar with their use. A number of scores have been developed for use in children and much work has been done in applying adult scores to paediatric casualties.

#### **3-5-1: The Paediatric Trauma Score**

The PTS is in widespread use in the USA where trauma care systems are regionalised. It is composed of specific components for the evaluation of anatomical and physiological changes that occur in injured children. The PTS was developed using multiple regression modelling of trauma registry data: the outcome measure was the ability of the score to correlate with ISS (such that a PTS under nine was predictive of ISS > 20; such a level of PTS may therefore be used as an indicator of patients who are T1 for triage tool assessment purposes). However, this chapter has argued that ISS is not necessarily an ideal outcome measure for use in the assessment of major incident triage methodologies, which thus casts doubt over the utility of the PTS in primary triage. At the present time, though, databases are insufficiently detailed to use alternative outcome measures.

Specifically the PTS uses the parameters in **table 3.6** to achieve a score for each child of between -6 and 12. In the USA a child receiving a PTS score of eight or below would be transferred to a trauma centre.

Component	+2	+1	-1
Size	>20 Kg	10-20 kg	<10 kg
Airway	Normal	Maintainable	Unmaintainable
SBP	>90 mmHg	50-90 mmHg	<50 mmHg
CNS	Awake	Obtunded / Loss of Consciousness	Coma / decerebrate
Open wound	None	Minor	Major / penetrating
Skeletal	None	Closed fracture	Open / multiple fractures

**Table 3.6: The Paediatric Trauma Score**

The reliance on the PTS of anatomical information (such as the presence or absence of skeletal fractures) limits its suitability as a pre-hospital major incident triage score. Similarly, because of the environment a full examination of a child is unlikely to be possible at the scene and these parameters are unlikely to be reproducible.

Reproducibility has been addressed for the PTS in a single patient situation between Emergency Medical Technicians and Emergency Physicians who use the PTS on a day-to-day basis (Ramenofsky et al, 1988). The reproducibility was found to be extremely good, with very few scores differing by more than one. Its reliability has not, however, been assessed in a multi casualty situation or when using non-experienced operators (which would be the case in the UK, where the PTS has not found widespread usage).

The PTS was designed to be used in all age groups: however, it is a poor discriminator in the very young. Children under the age of one year (below 10 kg) have a maximum score of 10 purely because of size: any injury in these children

would place them in the trauma centre group. This was a deliberate decision on the part of the original designers of the PTS who felt that all small children should be seen in trauma centres. Similarly, the designers stated that the PTS should categorise all patients with a head injury as having a maximum obtainable score of seven, which would result in all head injured children being categorised as major trauma.

The PTS requires both measurement (size, SBP, neurological assessment) and complete physical examination (wounds, airway, skeletal) in all patients. This requires a significant amount of time to be taken by the observer in examining the patient at the scene. Failure to be able to complete rapid triage may compromise the triage (and subsequent treatment) of other patients.

The PTS does not possess the characteristics of a pre-hospital triage score for major incidents. It may however find a place in the assessment of children at later stages in the response, such as at the receiving hospital where there may be more time available and better facilities. As the PTS is not in day-to-day use in the UK, it would also require pre-hospital teams and ambulance staff to be taught and practised in an entirely new method of triage: this is unlikely to be achievable at the present time.

### **3-5-1a: The Age Specific Paediatric Trauma Score**

In view of the difficulties in calculating an accurate PTS, Potoka *et al* undertook a trauma registry study to devise a novel, age specific paediatric trauma score (Potoka et al, 2001). They analysed almost 14000 children entered on a database to determine (n=9730 children) and then test (n=2248) the tool, which is based upon GCS, SBP, HR and RR as shown in **table 3.7**.

GCS	SBP	HR	RR	Coded value
14-15	Normal	Normal	Normal	3
10-13	Mild to moderate hypotension (< mean - 2 SD)	Tachycardia (> mean + SD)	Tachypnoea (> mean + SD)	2
4-9	Severe hypotension (< mean - 3 SD)	Bradycardia (< mean - SD)	Bradypnoea (< mean - SD)	1
3	0	0	0 / intubated	0

**Table 3.7: The Age Specific Paediatric Trauma Score**

Means and standard deviations were derived from the injured children on the database, and were presented graphically. When analysed for ability to predict ISS > 20, the tool was shown to have similar sensitivity to the RTS (but higher specificity). If a summed value of under 10 was taken as the threshold, the tool predicted mortality with a sensitivity of 97% and a specificity of 89%. However, the use of the tool is dependent upon relatively complex age related calculations, based upon age related physiological values. Hence, it appears to be useful for trauma scoring and system analysis, but has does not meet the criteria for a major incident primary triage tool.

### **3-5-2: The Trauma Score and the Triage Revised Trauma Score**

The TS was designed for use in adults in 1981: it was one of the first objective methods of trauma scoring developed. It is shown at **table 3.8**.

Coded value	5	4	3	2	1	0
RR		10-24	25-35	≥36	1-9	0
Respiratory Effort					Normal	Shallow
SBP		≥90	70-89	50-69	0-49	None
CRT				Normal	Delayed	None
GCS	14-15	11-13	8-10	5-7	3-4	

**Table 3.8: The Trauma Score**

The TS gives a score of between one and 16 for all casualties. Although its design was constructed from adult data, it has been considered by several authors for use in children. The TS has been directly compared with the PTS for predictive ability of major trauma in children, and there were few differences in the two scores (Nayduch et al, 1991). It has also been evaluated for its ability to predict serious injury (ISS 15+) in children. Chan *et al* in Australia examined the records of 1116 paediatric patients and concluded that the TS was a poor predictor of severe injury with a sensitivity of only 27% (though with a high [99%] specificity) (Chan et al, 1989). They noted difficulties in the application of adult variables in children, particularly the measurement of the GCS.

Nayduch *et al* compared the correlation between the PTS and TS in injured children (Nayduch et al, 1991). They found a strong positive correlation between the two scores and concluded that the PTS offered little advantage over the TS (as it is more complicated to perform). Comparisons were made between the ability of the two scores to predict patient outcome but the authors used an outcome measure (hospital admission) that is not a reliable predictor of injury as it may be affected by many extraneous factors, particularly in children. Similarly the scores were only used to correlate between the decision as to whether to transfer to trauma centres or

not. Again this is not a directly applicable clinical comparison to that of major incident triage.

Kaufman *et al* examined the correlation between PTS and RTS and found it to be highly significant (Kaufmann et al, 1990). They also compared the correlations between both scores and APACHE II score, admission physiology (GCS, SBP, RR), Haematocrit, need for operation and number of days in Intensive Care (ICU). Although both scores showed good correlation with all of these outcome measures, the RTS performed better. Comparison was also made of the scores' overtriage and undertriage rates. Triage to a trauma centre was considered for a PTS <9 or an RTS <12. The PTS had an overtriage and undertriage rate of 42.6% and 14.7%, respectively, compared to the RTS which had an overtriage rate of 19.5% and an undertriage rate of 23.5%. The RTS showed a greater overall accuracy for triage, particularly with regard to the overtriage rate which is of importance in major incidents. However, neither tool had acceptable undertriage rates, missing significant numbers of seriously injured children.

The results of the study, although encouraging for the RTS in children, should be interpreted with caution. The study was conducted from retrospective data in a level one trauma centre from single casualties. Its applicability to other situations (and in particular to the major incident environment) is therefore questionable.

Aprahamian *et al* also compared the abilities of the PTS and RTS to predict ISS (Aprahamian et al, 1990), using similar methods to Kaufman (Kaufmann et al, 1990). However, they found that the PTS was a better predictor than the RTS: the opposite result to that of Kaufman. The difference in these two results may be explained by the community-based approach of Aprahamian *et al*: they examined all

patients coming to the ED (Kaufman looked only at those patients admitted to hospital). Both authors suggest that their results may be used to select the appropriate score, but this clearly relates to the setting in which the score is to be used.

Eichelberger *et al* examined the relationships between the TS, RTS and PTS in children admitted to a paediatric trauma centre: they found no significant difference in the ability of the scores to predict major trauma (Eichelberger et al, 1989). By not triaging young children solely on the basis of a raised RR, they were able to show no significant difficulties when using the adult score. They concluded that when selecting a score issues such as the reliability, applicability to circumstance, and ease of use of the score should be considered. However, this study was conducted on single admissions to hospitals and not within the setting of a major incident: extrapolation of its findings to this situation is therefore difficult. Eichelberger *et al* felt that the RTS (with modification of the RR for small children) was the best of the three scores owing to its ease of use and established acceptance by many in the pre-hospital field (Eichelberger et al, 1989).

Because of impracticalities in its use, and imprecision in its findings, the TS was superseded by the RTS (Champion et al, 1989) in 1989 and is no longer in widespread use. Two modifications of the RTS were produced: the TRTS was designed as a triage tool and is the version considered in this thesis. The TRTS has been accepted by many as the best method for pre-hospital triage (Eichelberger et al, 1989; Advanced Life Support Group, 2002). It is calculated from three physiological parameters, each of which is assigned a score from zero to four points (a total of zero to 12 points) (**table 3.9**).



Score	SBP	GCS	RR
4	>90	13-15	10-29
3	76-89	9-12	>30
2	50-75	6-8	6-9
1	1-49	4-5	1-5
0	0	3	0

**Table 3.9: The Triage Revised Trauma Score**

The TRTS has been modified by the Advanced Life Support Group for use within the environment of a major incident: it is used for Secondary Triage at the CCS (the Triage Sort). For Triage Sort purposes, a TRTS of 12 indicates T3. A patient with a TRTS of 11 is T2, and anyone scoring 10 points or less is triaged as T1.

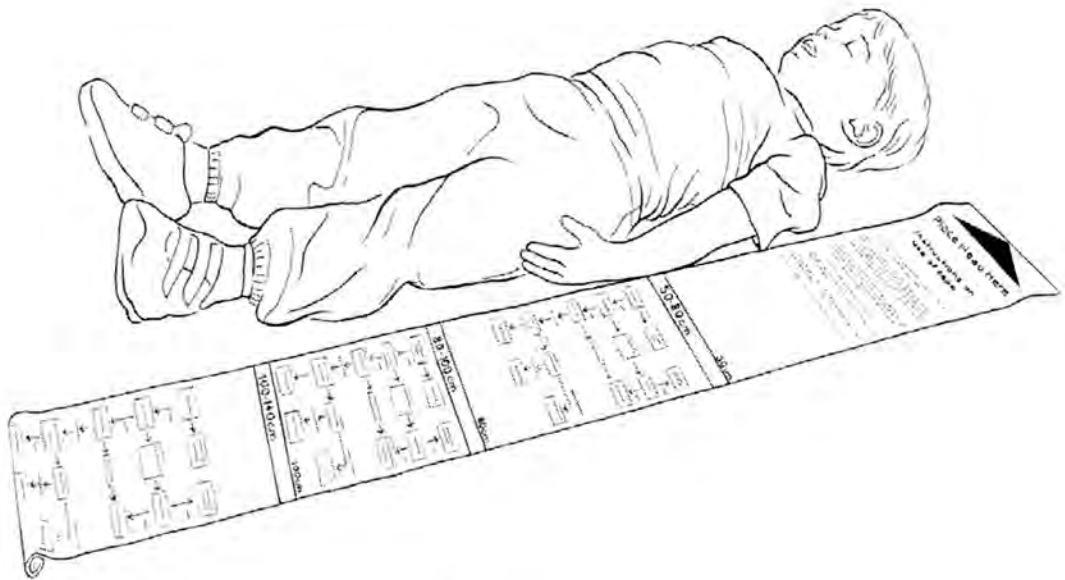
### **3-5-3: Paediatric Primary Triage Tools**

Two specific paediatric primary triage algorithms exist: the Paediatric Triage Tape and JumpSTART. In areas where CareFlight methodology is recommended for adults, the same algorithm is applied to children, although its ability in this regard has not been assessed.

As with the adult scores, all these tools include an assessment of the ability to walk, which has been shown to be useful where large numbers of patients are present with limited medical resources (Towne, 1995). Only the PTT makes allowance for children who may not be able to walk for developmental reasons, a group which may be overtriaged by other tools.

### 3-5-3a: The Paediatric Triage Tape

The Paediatric Triage Tape (Hodgetts et al, 1998) is a waterproof, non-tear tape that is an adaptation of the adult Triage Sieve. Its use is illustrated at **figure 3.4**. There is a centimetre scale along the edge of the tape.



**Figure 3.4: The Paediatric Triage Tape**

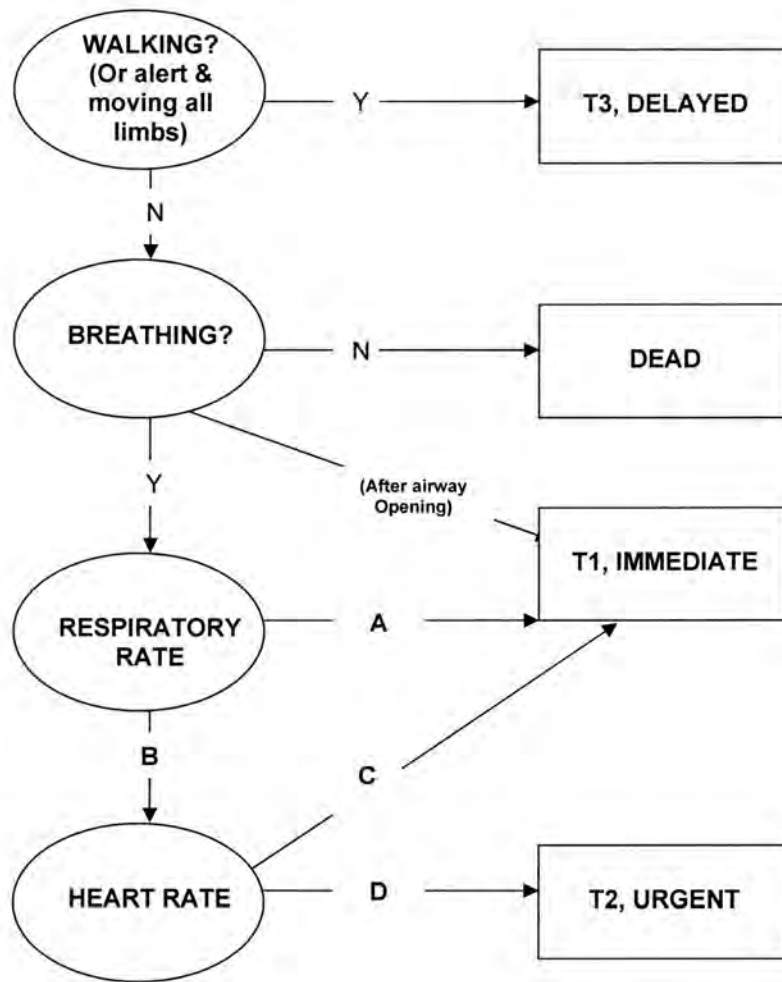
The tape is divided into four length / weight ranges:

- 50-80cm (3-10kg)
- 80-100cm (11-18kg)
- 100-140cm (19-32kg)
- >140cm (>32kg)

The same mobility / ABC assessment is made as is used in the Triage Sieve. For smaller children who are not yet able to walk, “walking” is replaced by “alert and moving all limbs”. This allows assignment to priority T3. If the child is not T3, the tape is opened and applied along the length of their body. Where the child’s heel touched the tape will determine which of the four algorithms is used. If the heel touches a boundary between two sections then the section for the longer child is used.

A child who is trapped and not accessible is T1, until they are extricated when the tape is used to reassess priority. Any child who is less than 50cm in length is also T1 (it is unlikely that such small children will be out of hospital). In accordance with the PTT’s instructions, children who are over 140cm (or 32kg) are triaged as adults. For children between 50cm and 140 cm, three blocks are used. The underlying algorithm is illustrated at **figure 3.5**. The same figure shows the ranges of physiological values to be used with each height block.

The PTT has been accepted in countries where the Major Incident Medical Management and Support course is taught (Advanced Life Support group, 2002). Although it is quick and simple to use, it is based upon non-validated physiological parameters. Furthermore, its ability to triage has not been formally assessed.



	50-80cm	80-100cm	100-140cm
<b>A</b>	<20 or >50	<15 or >40	<10 or >30
<b>B</b>	20-50	15-40	10-30
<b>C</b>	<90 or >180	<80 or >160	<70 or >140
<b>D</b>	90-180	80-160	70-140

**Figure 3.5: Paediatric Triage Tape: generic flowchart, physiological values**

### **3-5-3b: JumpSTART**

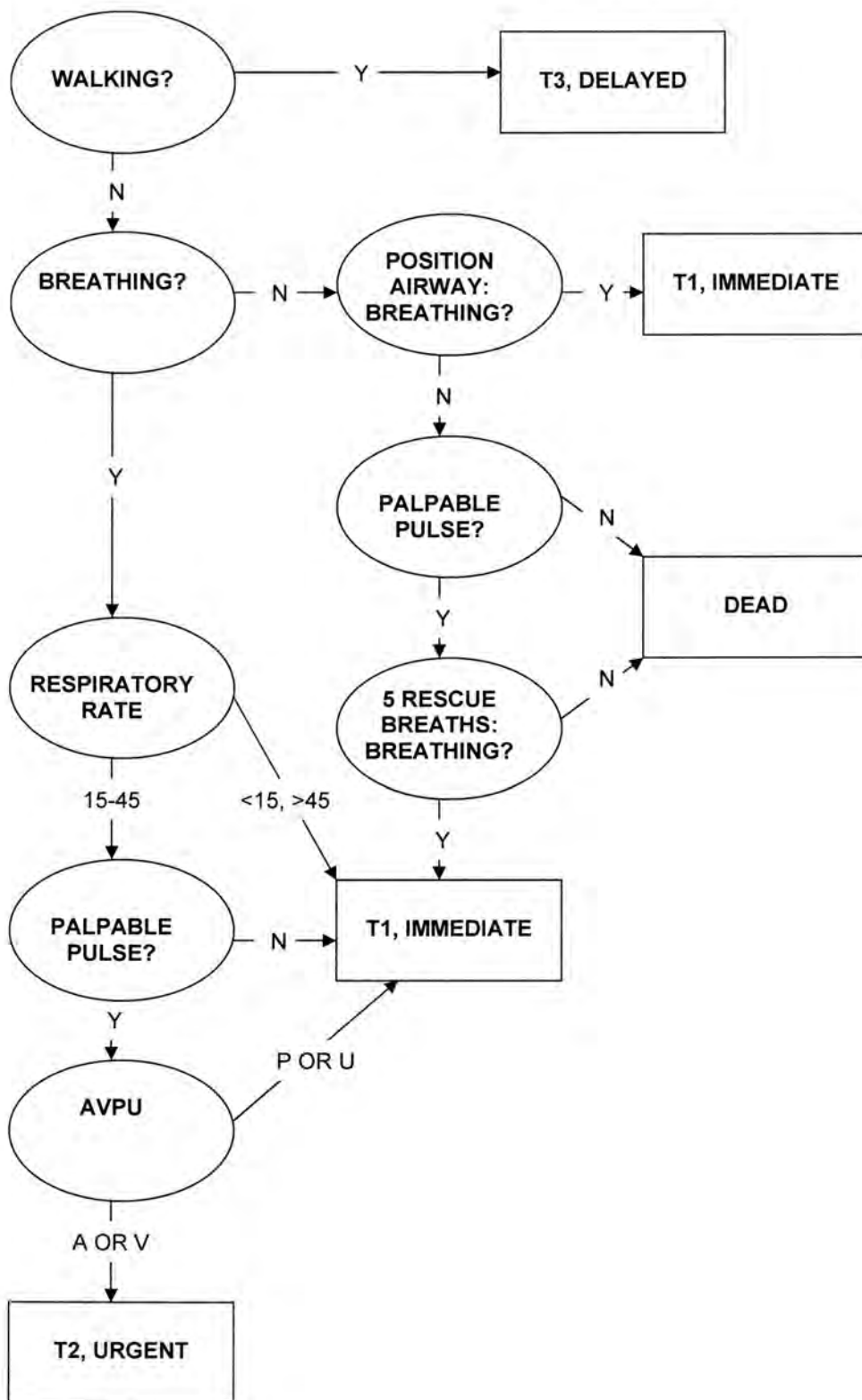
JumpSTART is a paediatric specific triage tool developed in the USA (Romig, 2002), using the same basic flowchart as START methodology with minor modifications. It is intended only for children one to eight years of age, and is illustrated at **figure 3.6**.

Children who are able to walk are triaged T3. Children who are developmentally unable to walk undergo the full JumpSTART assessment and, if they fulfil no T1 or T2 criteria, and they have no external signs of injury, they are then labelled T3.

An assessment of the presence of spontaneous breathing is then made: if no breathing is present, an attempt is made to open the airway. If this is successful and breathing starts, the child is T1. Otherwise a check is made for a pulse: absence of a pulse leads to triage as Dead; presence of a pulse necessitates five attempted rescue breaths – if the child still fails to breathe, they are Dead. If they start to breath at this time, they are T1.

If the child was already breathing spontaneously, the RR is checked: if under 15 or over 45 they are T1. Otherwise, a pulse is sought – absence of a pulse means the child is T1; presence of a pulse leads to an assessment of the child's AVPU status (in the UK, this means Alert, Responds to Voice, Responds to Pain, or Unresponsive. In the USA the P is replaced by Posturing which may be appropriate or inappropriate). A child who is P (inappropriate) or U is labelled T1; children who are A, V or P (appropriate) are T2.

**Figure 4.6: JumpSTART triage (next page)**



JumpSTART has not found widespread acceptance. It is longer than other existing primary triage schemes (especially for children with no spontaneous breathing and for developmentally non-ambulant children), determination of appropriate or inappropriate posturing is dependant upon a degree of medical experience not pre-requisite in other triage algorithms, and the physiological parameters for RR are not validated. Its ability to triage has not been formally assessed.

### **3-6: Summary**

- This chapter has examined some of the available methods of triage in the pre-hospital setting, and specifically some of the main issues with regard to triage of children. It is clear that specific methods of triage are required for major incidents. The suitability of the commonly used triage algorithms has been discussed.
- It would appear that a simple modification of the TRTS would be the best triage methodology for major incidents involving both children and adults. However, this finding is based upon studies that were not conducted on major incidents but rather were conducted on single casualties. Additionally, the TRTS is not suitable as a primary triage algorithm in its standard form.
- None of the current major incident primary triage tools have been validated for use on children. Furthermore, to date there has been no validation of a major incident score within a real major incident (and for practical reasons this is unlikely to ever happen). However, Garner *et al* (Garner et al, 2001) expanded on work by Baxt (Baxt and Upenieks, 1990) with the use of

outcome criteria as a means of testing triage tools. Garner used five criteria as markers of serious injury in major incidents, and this work can be developed further.



## **CHAPTER 4:**

### **BACKGROUND – VALIDATION OF TRIAGE TOOLS**

- 4-1 Introduction
- 4-2 Current Measurement Standards
  - 4-2-1 The Injury Severity Score
  - 4-2-2 The New Injury Severity Score
  - 4-2-3 The Paediatric Trauma Score
- 4-3 Consensus Criteria as Measurement Standards
- 4-4 Concepts in Validation of Major Incident Primary Triage Tools
- 4-5 Summary

#### **4-1: Introduction**

The difficulties in choosing an appropriate standard against which to test currently used triage algorithms have been identified (see **Chapter 1**). The use of the ISS is acceptable when testing an algorithm's ability to identify individual patients who may benefit from trauma centre care in a regionalised system. However, this cannot be extrapolated to a major incident setting where multiple casualties with different resource needs must be quickly and accurately identified.

Alternative options for testing major incident triage algorithms include the use of computer-modelled incidents using trauma registry databases. A computer-modelled incident could be generated with real patient data to illustrate how a major incident tool might work in a real incident. In order for this to be robust, an adequate database of major incident profiles would be needed (as would a suitable database of patient data). There are insufficient data to develop accurate major incident profiles at this time (although such systems have been proposed for the future (Carley et al, 1998)). Similarly, the present trauma registries are insufficiently detailed to predict major incident outcomes. This does present a potential for a future avenue of research into major incident triage.

At present, however, such triage instruments must be tested against established markers of severity, such as the ISS. This is far from ideal, and a suitable alternative needs to be identified. The basis for using expert opinion to validate triage tools has been established (Baxt and Upenieks, 1990; Garner et al, 2001), but can clearly be developed further.

The purpose of this chapter is to explore the currently available tools against which triage algorithms may be validated.

## **4-2: Current Measurement Standards**

### **4-2-1: The Injury Severity Score**

In 1970, the Association for the Advancement of Automotive Medicine developed a Committee on Injury Scaling. This committee developed two scaling systems, known as The Abbreviated Injury Scale (AIS) (Committee on Medical Aspects of Automotive Safety, 1971) and the Comprehensive Injury Scale (CRIS) (Committee on Medical Aspects of Automotive Safety, 1972). The CRIS was a detailed expansion of the AIS and never took off in common usage. The AIS was developed further, however, and the committee produced their first AIS dictionary in 1976, containing 500 injuries. These descriptions and severity scales were consensus derived by the committee, and graded in six degrees of severity.

The 1990 update contained 1200 descriptions, and this was re-issued in the 1998 version (Committee on Injury Scaling, 1998). Again, all scales remain consensus derived. The sixth edition is due to be launched in 2005.

In order to code patients accurately, information must be gained from patients' notes. There are problems with the degree of accuracy of the information recorded in notes, and this can affect the scoring that is assigned. Autopsy reports are the most accurate source of information for the data enterer, followed by operative notes. Hospital folders and trauma unit notes are often inaccurate or may contain contradictory information, but these are often the reference source for the inputted data.

The dictionary is divided into nine body regions, which are coded into six body areas:

- Head and Neck
- Face
- Chest
- Abdomen and Pelvic Contents
- Extremities and Pelvic Girdle
- External

All injuries are assigned a coded value and are entered into a database in one of these six body areas. The AIS code is a seven-digit number, with the first six digits containing detailed information about the specific injury. However, for the purposes of testing triage algorithms it is only the final digit that is of importance. This digit represents the severity of the injury and is coded as:

1. Minor
2. Moderate
3. Serious
4. Severe
5. Critical
6. Maximum (an inevitable death)

A maximum score is assigned if an injury causes death.

Once all injuries have been coded, the scores assigned can be used to produce an overall severity indication for that patient: the ISS. This is calculated from the three body areas with the highest severity scores; these three scores are squared and added together to form the ISS. It is important to note that this is not the three worst

values, but rather the worst values from three different body areas. The higher the ISS score, the more likely the patient is to die (a patient with a severity score of 6 is automatically given an ISS of 75). An ISS of 16 has been shown to correlate with a mortality rate of 10% (Boyd et al, 1987), and is accepted as the definition of major trauma for trauma centre care (Boyd et al, 1987; Cottington et al, 1988; Eichelberger et al, 1988). An ISS of 16 or higher may be regarded as indicating a patient with major trauma who should, therefore, be T1 (the 10% mortality rate was quoted in 1987 and has almost certainly reduced since that time, with improvements in patient care). An example will help to illustrate: **table 4.1**.

ISS body area	Injury	AIS code	Highest AIS	AIS <sup>2</sup>
head / neck	transected internal carotid artery	320212.4	4	16
	cerebral contusion	140604.3		
face	ear laceration	210600.1	1	1
abdomen	None			
extremities	fractured femur	851800.3	3	9
external	Abrasions	910200.1	1	
				<b>ISS = 26</b>

**Table 4.1: ISS scoring example**

The ISS in this example is 26: if the three worst scores had been taken, the cerebral contusion would be included (ISS = three) and the ISS would be 34 (this is the basis of the New Injury Severity Score, and is detailed below).

The ISS can be combined with information from the patient's presenting physiology (RTS), age and mechanism of injury (blunt vs. penetrating) to produce a weighted TRISS (**T**rauma **I**SS) score (Boyd et al, 1987). This score indicates the

patient's probability of survival (Ps) – this is not a measure of an individual patient's actual mortality but rather a statistical probability. If a patient has a Ps of 0.8, eight out of ten patients with the same injury pattern would be expected to survive. The Ps data for a given unit can be combined to allow comparison of the effectiveness of hospital systems in a given country: across border comparisons are also possible, although the same injuries in the same person will have different Ps in different countries as the TRISS methodology takes account of that country's overall management of trauma.

The ISS has been shown to accurately predict the likelihood of death from an injury, as well as correlating with post injury Multi-Organ Failure (MOF) (Sauaia et al, 1994; Sauaia et al, 1996; Sauaia et al, 1998). However, it makes no attempt to identify the resource requirements of patients, and of particular concern for major incident triage, it does not predict in any way the requirement for urgent medical intervention.

#### **4-2-2: The New Injury Severity Score**

To overcome some of the inadequacies of ISS in trauma scoring, the Anatomic Profile was devised (Copes et al, 1990). However, it is difficult to compute and has only been shown to be marginally better than ISS at predicting survival (Champion et al, 1990; Champion et al, 1996; Markle et al, 1992). One of the main limitations of ISS is that it does not recognise multiple injuries within the same body area, and so outcome prediction becomes inaccurate in patients with multiple injuries in one body area: in the example above the ISS of 26 changes to a New Injury Severity Score (NISS) (Osler et al, 1997) of 34 when the two head injuries are

considered together. This under-estimation of severity is likely to be worse in patients with severe head injuries, in whom the presence of more than one injury (for example, an extradural and a subdural haematoma) worsens the prognosis significantly.

NISS takes account of multiple injuries within one body region: it is simpler to calculate and more predictive of mortality than the ISS (Osler et al, 1997; Brenneman et al, 1998). It is also more useful at predicting post-injury MOF (Balogh et al, 2003). However, this is not the case in children where performance between the two tools is almost identical (Grisoni et al, 2001). The use of NISS has not taken off despite its apparent superiority, and is unlikely do so until TRISS methodology is widely superceded.

A NISS of 16 or higher may be considered to be an indicator of a T1 patient for triage algorithm validation purposes (Brenneman et al, 1998), but the same reservations apply to the use of NISS as an outcome indicator for the validation of major incident triage tools: the NISS is only looking at specific injury patterns, and not resource need.

#### **4-2-3: The Paediatric Trauma Score**

The PTS has been discussed (see **Chapter 3**). It was developed as a tool that correlates with ISS, and therefore the same limitations apply to its use as a gold standard for testing major incident triage algorithms. As identified, a PTS of less than nine correlates with an ISS of 20 or higher, and is therefore used as an indicator of a major trauma victim: this level is used in this thesis as the transition between T1 and not-T1.

### 4-3: Consensus Criteria as Measurement Standards

In 1990, Baxt and Upnekies (Baxt and Upenieks, 1990) challenged the use of the ISS in validating triage tools, on the basis that it is not only the severity of injury sustained that is important in determining whether a patient should be assigned a high medical priority. Clearly, if a patient has a reduced conscious level and, as a result, is unable to protect their airway adequately then they require immediate intervention: this will not be detected by ISS scoring. Similar arguments can be used for a number of interventions that may occur.

Baxt and Upnekies considered the major operative and resuscitative interventions that patients often require following injury (**table 1.3**). They also studied those patients who died from their injuries. The ISS did not correlate well with the requirement for these interventions: indeed, if an ISS of 15 or higher was considered as the marker of serious injury, 20% of these patients were missed.

Although not designed for a major incident setting, Baxt's findings are strongly suggestive that ISS is not an appropriate means by which to validate pre-hospital triage algorithms (the aim of which is to identify patients in need of urgent medical interventions). This work was further supported by comparisons of the American College of Surgeons trauma triage criteria, by Henry *et al* in 1996 (Henry *et al*, 1996a; Henry *et al*, 1996b). They argued that need for operative interventions (particularly time-critical operations) and ICU admission were more important than ISS in assessing the reliability of a triage tool.

This school of thought was further developed by Garner *et al* (Garner *et al*, 2001), who modified Baxt's original criteria to be more appropriate for a major incident setting. Garner compared three primary triage algorithms by their ability to



predict five criteria (**table 1.4**). Their findings in relation to the three primary triage algorithms for adults have been discussed (see **Chapter 3**). Of more importance however is the concept of using such criteria as a means of testing triage tools.

Garner used these criteria to identify critically injured patients who should be triaged as T1 by the tool being tested, on the basis that the need for these interventions indicated serious injury. Garner's criteria were developed for adult patients but are directly transferable to the paediatric situation, with the exception of the requirement for 1000ml fluid resuscitation. For this thesis, this criterion has been replaced by the requirement for 20ml of fluid per kilogram of body weight (as accepted for first line fluid resuscitation (Advanced Life Support Group, 2005)) (**table 4.2**).

<b>Intervention</b>	<b>Description</b>
Operative intervention	(Non-orthopaedic; within 6 hours)
Fluid resuscitation	(> 20 ml/kg)
Invasive CNS monitoring	(Or a positive head CT scan)
A procedure to maintain the airway	(Or assisted ventilation)
Decompression of a tension pneumothorax	

**Table 4.2: Garner criteria modified for children**

The criteria used by Garner *et al* were modified from those used by Baxt. Both sets of criteria were used on the basis of expert opinion (that of the authors), although these interventions are necessarily limited in scope. Now that the use of expert derived criteria as markers of outcome has been established, research into

triage algorithms can progress using this tool. If this method is taken a step further, a group of experts may be used to derive a list of criteria against which to judge a triage algorithm. Such a method is preferable to the use of the ISS (or NISS or PTS) as it allows for correct identification of casualties based upon medical need, rather than on specific injury severities alone.

The first step in such methodology is the derivation of a list of suitable criteria. These criteria may be independently derived for testing major incident triage algorithms, specific paediatric major incident triage algorithms, or any other form of triage tool. Criteria that may be used as indicators of severity in one situation may not be applicable to another: for the testing of major incident triage algorithms, a dedicated list of criteria must be derived.

The derivation of appropriate criteria to test against may be by committee, as is the case in the AIS (the system on which ISS scoring is based), or by alternative means. The most scientifically valid means of determining consensus is through Delphi methodology (Rowe et al, 1991).

#### **4-4: Concepts in Validation of Major Incident Primary Triage Tools**

The limitations of using traditional standards, such as ISS, in validation of major incident triage algorithms have been presented. Expert opinion or consensus-derived criteria may provide a more robust alternative means of undertaking such validation until trauma registries and computer modelling allow more accurate assessment. However, in practical terms one must consider how the validation process will be undertaken. Delphi consensus methodology may become more widely accepted as a validation tool: however, for now traditional gold standards

must still be used, despite their limitations. They may be used in conjunction with expert criteria during a validation study.

The use of an ISS of 16 or higher as a marker of major trauma is well established in regionalised systems of health care such as the USA (although systems using the PTS accept that this tool is trying to identify patients with an ISS of 20 or more). As this level of ISS is associated with worse outcomes, it seems appropriate to use ISS 16+ as a marker of those patients who should be identified as immediate (T1) in a major incident setting (although this will not identify patients with immediately life threatening problems but low ISS – such as those with airway obstruction). However, the group of patients with an ISS of 15 or below may contain some people who should be triaged as T2 (urgent) and some T3 (delayed). ISS does not allow for differentiation between these groups. For this reason, whilst ISS 16+ may continue being used as a marker of immediate priority, an ISS of 15 and below is of no discriminatory value.

The same reasoning may be applied to the NISS (values of 16+ indicating T1), and also the PTS (values of eight and below indicating T1).

The criteria used by Baxt and Upnekies (Baxt and Upenieks, 1990b) and Garner *et al* (Garner et al, 2001) were derived specifically to identify patients in need of immediate interventions. Baxt's work, however, was not aimed at a major incident setting, and cannot be considered as a means to test major incident triage tools. Garner's criteria may be used to test a triage algorithm's ability to identify T1 patients, but (like other traditional measurement standards) have no discriminatory value between T2 and T3.

Criteria derived by Delphi methodology may be explicitly directed at identification of T1 patients. However, the Delphi study undertaken for this thesis aimed to derive suitable criteria to identify T1, T2 and T3 patients. These criteria include specific interventions that may be required for patients in major incident.

For the validation of the PTT, therefore, the Delphi derived criteria may be used to test the PTT's ability to identify T1, T2 and T3 patients. The ISS, NISS, PTS and Garner criteria may be used to test the PTT's ability to identify T1 patients (although there are reservations about this usage).

#### **4-5: Summary**

- Although long regarded as the only means by which to test a triage algorithm's ability to detect seriously injured patients, there is good evidence that ISS actually misses many of the very people it is aiming to detect.
- Henry *et al* used interventions as outcome markers, and both Baxt and Upnekies and Garner *et al* have demonstrated in peer-reviewed journals that it is appropriate and possible to use consensus based criteria to determine the performance of a triage algorithm. This can be developed through the use of Delphi methodology to derive a full set of criteria that may be taken as indicators of those patients that a triage algorithm should identify as immediate priority. The same process may be used to identify patients who are of urgent (T2) or delayed (T3) priority.
- To validate a major incident triage tool, ISS is still seen by many as the only acceptable gold standard. This (along with the other standards that will be applied) may only be used to demonstrate a tool's ability to identify T1 / not

T1 patients. The Delphi criteria derived in this thesis may be used to test a triage tool's ability to identify T1, T2 and T3 patients.

**CHAPTER 5:**  
**BACKGROUND – REFERENCE RANGES OF HEART AND**  
**RESPIRATORY RATES IN CHILDREN**

- 5-1 Introduction
- 5-2 Respiratory Rate
- 5-3 Heart Rate
- 5-4 Height and Weight Related Values
  - 5-4-1 Respiratory Rate
  - 5-4-2 Heart Rate
- 5-5 Physiological Values in Children in Developing Countries
- 5-6 Summary

## 5-1: Introduction

In all aspects of medicine, clinical decision-making relies on the history, examination and the results of selected investigations. As part of the general clinical examination, four vital signs are routinely recorded: the HR, RR, blood pressure and temperature. Due to advances in monitoring technology, ease of use, and unreliability of clinical observation (Edmonds et al, 2002), the only one that is still regularly measured clinically in the UK is RR (Lovett et al, 2005). Blood pressure is typically measured with an electronic cuff which also provides HR information – the latter is often alternatively derived from an oxygen saturations machine if SaO<sub>2</sub> is being recorded. There are several means of recording temperature, but electronic thermometers are becoming increasingly common.

Several parameters have battled for the title of the “fifth vital sign”, including pain measurement, GCS, CRT and SaO<sub>2</sub> (Lovett et al, 2005). Of these, variations of the GCS (typically an assessment of the ability to follow commands) and measurement of the CRT are often included in triage algorithms (Advanced Life Support Group, 2002; Champion et al, 1981).

In consideration of the PTT, three physiological variables are important: RR, HR and CRT. The evidence behind values of CRT in children appears sound (see **Chapter 1**). However, despite reliance on the use of reference ranges of HR and RR in children, there appears to be little or no evidence to support the values on which we depend. The ranges that are quoted by various texts and courses vary widely (**table 1.2**).

This chapter considers the evidence that exists in support of quoted ranges of these parameters.

## 5-2: Respiratory Rate

Most (but not all) clinicians agree that RR is a useful and important sign to measure (Kory, 1957). However, there are little data to support the values that are given as “normal”, and most cannot be considered applicable to healthy children in the developed world of the 21st Century. Available studies fall into two groups: those looking at children who are ill or are attending Emergency Departments (ED), and those looking at the RR of healthy children at rest. The latter are summarised in **table 5.1**.

Authors	n	Age range	Comments
Quetelet, 1842	u/k	u/k	Unknown numbers and ages; 160 year old data
Shock, 1968	55	11-17	Small numbers; examined in laboratory; limited age range
Iliff and Lee, 1952	188	0-18	One mile altitude; children asleep & awake
Cook et al, 1955	25	0-1/12	Limited age range
Nelson et al, 1962	38	0-1/12	Limited age range
Voors et al, 1982	3590	5-17	No reference ranges presented; examined in laboratory
Marks et al, 1993	416	1-7	Measured by thermocouple; sleeping and awake
Rusconi et al, 1994	618	0-3	Limited age range

**Table 5.1: Evidence base for heart and respiration rate**

There have been a number of studies in the first group. These give useful information, but none can be applied to healthy resting children. Morley *et al* (Morley et al, 1990) studied babies up to six months of age who had signs of respiratory infection: data on older children with respiratory problems is in plentiful



supply (Morley, 1991; Redd et al, 1994; Gadomski et al, 1994; Smyth et al, 1998; Onyango et al, 1993).

In 1992 Hooker *et al* presented a series of 434 children presenting to an ED, concluding that RR was inversely proportional to age (Hooker et al, 1992): the data provided mean, SD and range values for each year from birth to 18 years. However, although children presenting with fever or primary cardiorespiratory symptoms were excluded, the study made no allowance for changes in respiratory rate due to pain, symptoms unrelated to the cardiorespiratory system or simply the anxiety of being in a hospital ED. Furthermore, rates were recorded by different duty triage nurses, introducing an unquantifiable element of inter-observer variability and reducing the reliability of these measurements (Edmonds et al, 2002).

The first available data in resting children came from Quetelet (Quetelet, 1842), who studied respiratory rates of up to 300 patients, including an unknown number of children at birth, 5 years and 15-20 years. However, this was in 1835 and the data cannot be generalised to a modern setting: we do not know their state of health or where they came from. In 1952, Iliff & Lee (Iliff and Lee, 1952) produced reference ranges for RR, but they measured only 188 children in total (birth to 18 years) and the children were either awake or sleeping, which leads to difficulties in interpreting the data. Furthermore, these children lived in Denver, Colorado at one-mile altitude where the lower partial pressure of Oxygen could have significantly influenced the results.

Cook *et al* (Cook et al, 1955; Cook et al, 1957) and Nelson *et al* (Nelson et al, 1962) both published small data series (25-38 children) on children up to one month of age, but had no data on older children. In 1993, Marks *et al* (Marks et al, 1993)

published a data set of 416 children from one to seven years of age (293 awake, 123 sleeping). From these data, reference centiles were produced for RR both awake and asleep. There are two major limitations in their data: firstly, although the children were at rest when they had their data recorded they were made to wear a nasal thermocouple to undertake the reading - there is evidence that applying any form of mechanical device to measure respiratory parameters induces changes in the value recorded (Gilbert et al, 1972). Secondly, although nasal thermocouples have been shown to be accurate in measuring RR (Marks et al, 1995), this is not the method that is used in routine clinical practice, namely direct observation (with or without the use of a stethoscope).

The most reliable data on resting breathing rates in children come from Rusconi *et al* (Rusconi et al, 1996), who reported 618 children aged 15 days to three years, quietly resting or asleep. These children had their RR measured by direct auscultation with a stethoscope for one minute. This data was used to produce age related centile curves. Rusconi found that RR:

- Drops rapidly from birth to three months of age.
- Norms are widely spread for a given age, with most variation in the first three months of life.

From the available research, therefore, reference values that are reliable and are of use in well children in the Western world are only available up to three years of age (Rusconi et al, 1996).

### 5-3: Heart Rate

Once again, there is scant evidence in support of the values that we accept for our day-to-day practice as “normal”. Available data regarding normal resting HR in children come from four main sources. All have limitations that prevent their extrapolation to healthy resting children in the United Kingdom of the 21<sup>st</sup> Century.

In 1944 Shock produced data on resting HR in five boys and 50 girls aged between 11 and 17 years (Shock, 1968). However, the children were examined in a laboratory while fasting; furthermore, the data represent only a small sample of a restricted age group, and measurements were made 60 years ago.

Iliff and Lee undertook measurement of HR in children aged between one and 18 years old, both awake and asleep (Iliff and Lee, 1952). The sample size was 197, with small numbers in each year group, and the data are now 50 years old. Furthermore, these children are likely to have been affected by the one-mile altitude at which they lived.

Data were collected in 1978 by Voors *et al* in Bolagusa, New Orleans, on 3590 resting schoolchildren aged five to 17 years, as part of a bigger epidemiological study (Voors *et al*, 1982). These data were recorded in a hospital laboratory environment, which could have an unquantified effect on the heart rate recorded (Gilbert *et al*, 1972). Their research efforts were concentrated on the epidemiology of hypertension, and the data on resting HR were only presented as unsmoothed centile charts: age ranges are not provided.

Dark (Dark *et al*, 2002) recently produced data on heart rate in 10600 children of all ages: however, the study was aimed at producing reference ranges for injured and sick children, not a “normal” resting population. Furthermore, data were

taken from multiple hospitals over a period of ten years, allowing for a degree of interobserver error in those recording the HR (Edmonds et al, 2002). There is no reliable, contemporary evidence for resting HR in healthy children.

## **5-4: Height & Weight Related Values**

### **5-4-1: Respiratory Rate**

One of the problems identified in the data produced is that there is a wide spread of height and weight values in any given year age group, which might account for a wide spread of resting vital signs. There is good evidence that RR is linked to body size in many animals (Guyton, 1947; Mortola, 1987; Crossfill and Widdicombe, 1961). That RR decreases as size increases is not new knowledge: Bert (cited in Mead (Mead, 1963)) noted in the nineteenth century that mice breathe 100 times faster than elephants, although they are around a million times smaller. There is an inverse (allometric) relationship between body mass and RR in mammals (Heusner, 1983) following the equation:

- Respiratory rate =  $a \cdot \text{body weight}^b$

(where a and b are constants, differing for each mammal).

However, how this relationship develops in humans is not known. In their work, Gagliardi and Rusconi (Gagliardi and Rusconi, 1997) concluded that there is an inverse relationship between RR and body weight in children up to three years of age, and that the rate per unit body weight is not constant but decreases as body weight increases. They produced weight related centile curves for RR. However, the

use of such weight related values has not found widespread acceptance. These data only apply up to three years of age.

#### **5-4-3: Heart Rate**

There are no available data relating paediatric HR to weight or height.

### **5-5: Physiological Values in Children in Developing Countries**

Children growing up in developing countries are subject to different survival pressures from their counterparts in the UK: lack of natural resources, combined with poverty and disease, make childhood a struggle in many parts of the world. Added to this burden, sub-Saharan Africa is faced with a pandemic of HIV infection, which affects 11% of the population in South Africa (although infection rates are higher in certain parts of the country) (Dorrington et al, 2004). HIV infection predisposes affected children to infectious diseases that they may otherwise avoid, and contributes to malnutrition and poor growth. According to the World Health Organisation, in 1999 9.2% of one to five year old children in South Africa were malnourished (more than two standard deviations below the mean from their age) (World Health Organisation, 2005).

Added to this background of poverty, hunger and disease, South African children suffer an epidemic of trauma (Bradshaw et al, 2003). This high incidence of trauma makes South Africa an appropriate location in which to undertake this study. However, the PTT was designed primarily for use on children in the UK and makes assumptions about physiological derangement based on the currently accepted ranges

of physiological values in the UK. It is not known whether the physiological normal ranges for children in South Africa are the same as those in the UK.

Data concerning height or weight development in the third world are scant. There are some data concerning the growth of ethnic minority immigrant populations in the UK (Kelly et al, 1997; Rona and Chinn, 1987), which suggest that these children adopt similar growth characteristics to their peers in their adopted country reasonably quickly. A similar paper concerning Japanese immigrants to the USA came to the same conclusion regarding adoption of growth patterns of the adopted country (Greulich, 1976). However, it is not clear whether this information can be extrapolated to children in their native countries as healthcare access and provision, public health and nutritional status are all likely to be considerably different in the adopted country.

Even concerning ethnic minorities in the UK, data are mixed. A 1986 study (Rona and Chinn, 1986) found that Gujarati children were typically smaller than white children in England, but that African and Caribbean children were taller than whites. Weight was found to be even more complex, with African children tending to have slightly higher weights than their white peers, but Indian sub-continent children varying dependant upon their region (Urdu, Punjabi or Gujarati) (Chinn et al, 1992). Gatrad *et al* (Gatrad et al, 1994) reported on five Asian subgroups in the UK, and found similarly mixed data – some groups were heavier and taller than their white controls, whilst others were considerably smaller.

Furthermore, more recent data suggest that populations in the UK, USA and other developed countries are becoming more obese, which may skew growth charts

produced in these countries (Troiano and Flegal, 1998; Kuepper-Nybelen et al, 2005; Stenhouse et al, 2004) and complicate the pattern of relationship even more.

With regard to children studied in their native countries, a 1980 paper from West Bengal (Hauspie et al, 1980) suggested that growth there was typically below the 10<sup>th</sup> centile of that in the UK: however, the usefulness of these data is limited as they were collected between 1952 and 1966, and comparisons were made to old Tanner-Whitehouse charts (Tanner and Whitehouse, 1976), which have since been replaced in the UK.

Growth of children on the Indian subcontinent was studied in the 1980s (Akram and Agboatwala, 1991): these children were noted to be approximately one centile line below similar aged children in the UK. These findings have been questioned by studies on immigrant populations in the UK (Kelly et al, 1997), but early data from Iran, Nigeria and the Gambia (Amirhakimi, 1974; Janes, 1974; Janes, 1970; McGregor et al, 1961; McGregor et al, 1968) suggest that social differences are more important than background ethnic group. Both of these studies compared growth in ethnically similar children in differing socio-economic groups: Iranians and Nigerians, when well nourished, turn out as tall as their British counterparts. Farquharson (Farquharson, 1976) undertook a similar study, comparing differing socio-economic groups of Nepali children to determine whether a genetic or environmental reason lay behind their typical small stature. She found that growth patterns demonstrated stunting due to early malnutrition rather than genetic small stature, which was much less marked in the wealthier groups. Tanner (Tanner, 1976) concluded that growth charts for developing nations should be based upon the growth of the wealthiest subset of the population, with national performance against

these charts being used to monitor the success or otherwise of public health and social improvements.

There are no papers looking at growth of South African children. Furthermore, most data from developing countries are old, and determining whether growth patterns have changed with improvements in public health and hygiene in many affected countries is not possible without further study. It is therefore not possible to extrapolate these articles to the population of interest for this study.

Growth in chronic disease states and malnutrition is known to lag somewhat behind that of healthy children in developed countries (Farquharson, 1976; Thomas et al, 2000; Morison et al, 1997)): one could extrapolate this to the Third World setting but the extent of this relationship is not clear. There are no data concerning the magnitude of this effect in South African children.

With regard to HR and RR, there are no reference ranges for children in South Africa (or in the developing world generally). There are some data on RR in children with a variety of medical conditions, most notably respiratory infections (Smyth et al, 1998) or malaria (O'Dempsey et al, 1993). However, these are of no help in determining values for "normal" healthy children. There are no data relating HR or RR in developing world children to their height or weight.

Finally, there is no evidence concerning the physiological response to trauma of children in the developing world, and there is no evidence that this population will respond differently to trauma than their counterparts in the developed world. There is no reason to believe that the response to trauma will differ between different countries' populations.



To ensure that the validation of the PTT is undertaken correctly, it is necessary to determine whether resting physiological values in the population served through the Trauma Unit at RXH are the same as those in the UK for whom the PTT was designed.

### **5-6: Summary**

- There is no current evidence to support the widely published and accepted reference ranges of HR and RR in resting, healthy children. Available data all have serious flaws through age of the results (children in the 1800s, 1950s and 21<sup>st</sup> Century are not necessarily the same population); children living at high altitude; measurement in a hospital or laboratory setting (with an unknown effect on the values recorded), or measurement of sick or injured children.
- There are no useful data regarding these ranges in developing countries, or relating HR and RR to weight or height.
- There is a need to have accurate and up to date values for these parameters if we are to make clinical decisions based upon abnormal findings in their measurement.

**CHAPTER 6:**  
**REFERENCE RANGES OF HEART RATE AND RESPIRATORY**  
**RATE – UNITED KINGDOM**

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- 6-2 Methods
  - 6-2-1 Choice of Schools
  - 6-2-2 Consent
  - 6-2-3 Data Collection
  - 6-2-4 Sample Size
  - 6-2-5 Statistical Methods
- 6-3 Results
  - 6-3-1 Demographics
  - 6-3-2 Height and Weight
  - 6-3-3 Physiological Values
    - 6-3-3a: Respiratory Rate and Heart Rate Related to Height and Weight
    - 6-3-3b: Heart Rate
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    - 6-4-6a: Ambient Temperature
    - 6-4-6b: Peripheral Cutaneous Oxygen Saturations
    - 6-4-6c: Capillary Refill Time
- 6-5 Summary

## 6-1: Introduction

In order to establish abnormal ranges for the physiologic variable of interest for primary triage tools – heart rate and respiratory rate – it is important to first understand the range of these values in healthy, resting children. As there is no evidence for these values in children, it is necessary to undertake a study to determine such reference ranges. Once these data are collected and analysed it will be possible to establish whether they have the same ranges in the population on whom the triage tool is being validated (in South Africa).

This chapter is concerned with deriving such reference ranges, and also considering those ranges currently taught to healthcare professionals in medical texts and on the popular Paediatric Life Support courses.

This study was undertaken in Plymouth, UK. Plymouth is a fairly typical medium sized city, with a population of 240,000, and around 4% unemployment rate (Office of National Statistics, 2003). The ethnic mix in Plymouth is considerably less than in many towns (235,000 of the population are white). The extent of the influence that this has on the results, if any, is unclear, as there is good evidence that the height and weight standards of ethnic populations in the UK quickly adopt the values of their UK born peers (see **Chapter 5**).

There is recent evidence that young Plymouth children (born in 1996 – 1997, measured at age 24 months) are heavier than the standard UK centiles (Stenhouse et al, 2004): the mean difference from the centile chart was 0.33 standard deviations (460g). These results may not necessarily be applicable to older Plymouth children (born pre-1996), who form the bulk of this study (the youngest children were aged four years, born in 1997). Furthermore, the absence of similar data from other UK

towns does not mean that Plymouth is abnormal – these data may be fairly typical. but in the absence of further articles this is not yet clear. Population data suggest that Plymouth children may be considered fairly representative of children in the UK, albeit from a limited ethnic mix.

## **6-2: Methods**

Ethical approval was obtained through the South Devon Local Regional Ethics Committee.

### **6-2-1: Choice of Schools**

The sampling procedure sought to take account of the structure of the education system in England, both by selection procedure and geographical spread. Schools were stratified by education area board and school selection policy (grammar and non-grammar). For each stratum, a two-stage cluster sample of children was obtained. The primary sampling units were the schools randomly selected with probabilities proportional to school size. The secondary units were the children randomly selected from the appropriate age-sex groups within the schools.

### **6-2-2: Consent**

The headmaster of the school was approached in person and the study detailed to him / her. If they agreed that the school would participate then the school children were briefed about the study by the author in their weekly assembly. Information regarding the study was sent to the parents of each child in the school (**appendix 1**). The parents or guardian of each child were asked to sign the consent

form shown at **appendix 2**. Children aged 12 years and over were asked to sign their own consent forms in addition. Children were excluded from the study if consent was refused or the form was not returned.

A notification sheet was prepared for family doctors and parents: these are shown at **appendices 3 and 4** respectively.

### **6-2-3: Data Collection**

All children were seen in their school by the author, in the presence of a female nurse chaperone, between May and December 2001. Children were brought out of their classrooms and left to sit quietly outside the study room for five minutes.

The child then sat quietly in a warm, well-lit classroom while their RR was measured by direct observation by the author. They then had their HR and peripheral cutaneous oxygen saturation measured for 60 seconds using a Datex S5 Lite® monitor. A finger probe was used in all cases. Recording did not commence until a suitable trace with a regular, pulsatile waveform was achieved continuously for 20 seconds. Ambient temperature in the room was recorded at the same time. Data were transferred real time to a computer, using Datex software: recordings were made at 5-second intervals for 60 seconds. The mean of these recordings was registered as the child's HR.

Capillary refill time was measured by direct pressure on the child's forehead. A calibrated stopwatch was used to time the five seconds of pressure and the time to return of normal skin colour.

Children then had their standing height recorded using a Leicester height meter, and weight using scales calibrated by the department of medical physics at Derriford hospital, Plymouth.

Children who were unwell on the day of the study (but were well enough to attend school) were still included in the sample, as were children with diagnosed or undiagnosed medical conditions. No attempt was made to identify these children in the database.

#### **6-2-4: Sample Size**

To achieve a standard error of the limits of the reference range of 5% of the (estimated) standard deviation of the reference variable (for each one year age group) requires an overall sample size of 1169.

#### **6-2-5: Statistical methods**

Age was recorded as the age in years at the preceding birthday. The data were therefore treated as 13 separate frequency distributions, one for each year of age from four to 16. Height and weight data were plotted against the standard growth reference charts in current use in the UK (the UK 90 charts (Freeman et al, 1995)). Data were plotted at the mid-point of that year group: data for 12 year olds were plotted at 12.5 years on the growth chart.

The exact methods used to produce reference ranges were determined in part by the results obtained, as the requirement for logarithmic transformation and calculation of centile curves is dependant upon the normality of the data. The details are provided in the results section.

## 6-3: Results

### 6-3-1: Demographics

Six schools took part in the study, with a total of 3592 pupils. 1153 children agreed to participate, but 44 failed to show to have their data collected. A total of 1109 children aged from four to 16 years were assessed.

The spread of ages is shown in **table 6.1**. Six hundred and one of the children (54.2%) were female. The age ranges and means are in **table 6.2**. The smallest group was the four year olds, with 49, and there were 162 twelve year olds.

Age	Male	Female	Total (%)
4	27	22	49 (4.4)
5	39	30	69 (6.2)
6	43	57	100 (9)
7	35	38	73 (6.6)
8	46	42	88 (7.9)
9	20	56	76 (6.9)
10	40	23	63 (5.7)
11	68	42	110 (9.9)
12	55	107	162 (14.6)
13	43	65	108 (9.7)
14	36	59	95 (8.6)
15	28	28	56 (5.1)
16	28	32	60 (5.4)
<b>Total</b>	<b>508</b>	<b>601</b>	

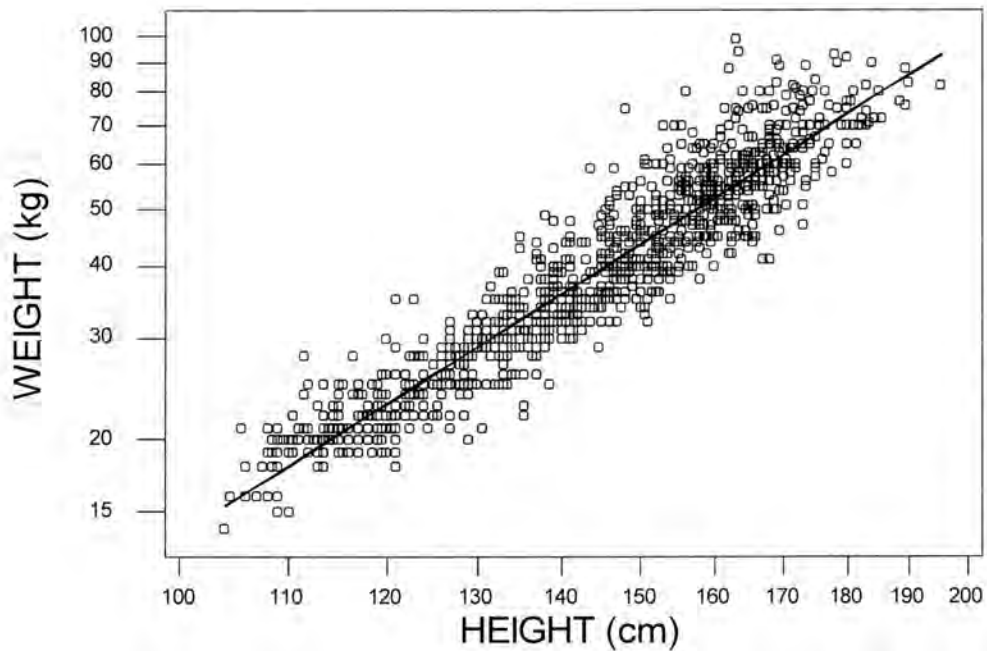
**Table 6.1: Spread of sex and ages, UK children. n= 1109**

	Male	Female	Total
<b>Range</b>	20-68	22-107	49-162
<b>Mean</b>	39.1	46.2	85.3
<b>Median</b>	39	42	76

**Table 6.2: UK children, group size data - range, mean and median in each one-year age group. n=1109**

### 6-3-2: Height and Weight

The relationships between age, height and weight are shown in **figures 6.1 - 6.3**. Height was found to increase by 3.8% with each year from age 4 (range 104-194.5cm, mean 144.5cm). Weight increased by 11.4% per year (range 14-99kg, mean 41.5kg).



**Figure 6.1: UK children, height (cm) against weight (kg). n=1109**

The mean height and median weights are shown in **table 6.3**: these data were plotted against UK 90 growth charts and found to lie between the 50<sup>th</sup> and 75<sup>th</sup> centiles for both boys and girls.



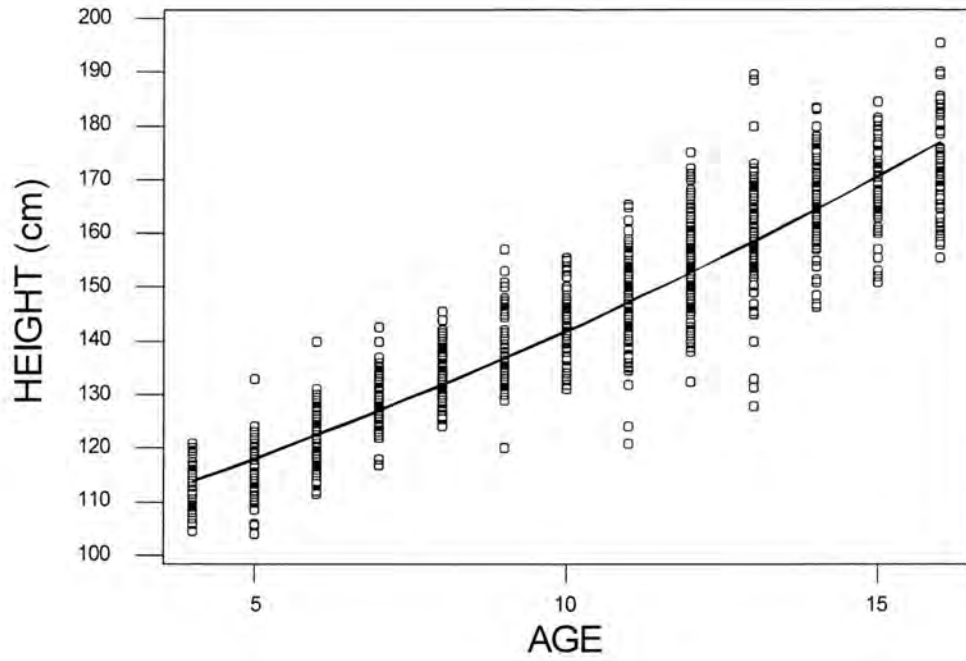


Figure 6.2: UK children, height (cm) against age (years). n=1109

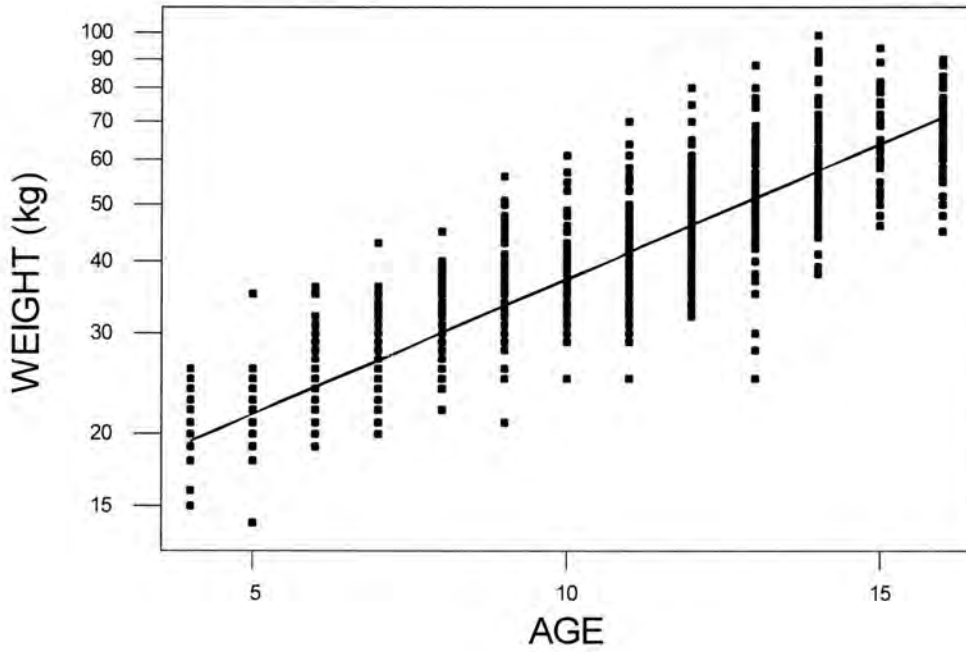


Figure 6.3: UK children, weight (kg) against age (years). n=1109

Age (years)	Mean height (cm)		Median weight (kg)	
	Boys	Girls	Boys	Girls
4	112.8	112.0	20	19
5	114.7	115.0	20	20
6	121.4	121.9	24	24
7	129.6	128.7	26	25
8	134.3	133.7	31	30
9	141.5	138.7	35	34
10	143.2	143.1	36	35
11	146.0	149.0	40	40
12	152.7	154.9	45	49
13	161.5	159.1	51	54
14	169.3	163.1	62	55
15	173.7	162.7	70	61
16	178.2	165.9	71	60

**Table 6.3: Height and weight of UK sample. n=1109**

### **6-3-3: Physiological Values**

#### **6-3-3a: Respiratory and Heart Rate Related to Height and Weight**

The correlations of HR and RR with height and weight were calculated. All were small; the average correlations with height were  $-0.10$  for Hr and  $-0.03$  for RR, while those for weight were  $-0.22$  for RR and  $-0.15$  for HR.

#### **6-3-3b: Heart Rate**

Calculation of the cumulant ratios (Fisher 1946) showed that the HR distributions were slightly skew to the right. This was corrected for by logarithmic transformation. The means and standard deviations of the transformed data were calculated and smoothed by cubic and linear polynomials respectively. Upper and lower reference limits were calculated as mean  $\pm 1.96$  Standard Deviations (SD) and

back-transformed. The fitted equations for the mean and SD of HR were (where 'age' denotes age at last birthday):

- Mean  $\log_{10}(\text{HR}) = 1.941 - 0.003293 \times \text{age} + 0.000652 \times (\text{age}-10)^2 - 0.0002861 \times (\text{age}-10)^3$
- SD  $\log_{10}(\text{HR}) = 0.04745 + 0.001709 \times \text{age}$

The observed values are shown in **table 6.4**. The values are shown as integers, rounded towards the median, with 95% reference interval (2½, 97½ centiles).

Age (years)	Heart Rate (bpm)*			Respiratory Rate (rpm)**		
	2.5	50	97.5	2.5	50	97.5
4	81	103	131	20	22	26
5	74	95	121	19	21	25
6	69	89	115	18	21	24
7	66	85	111	17	20	24
8	63	83	109	17	19	23
9	62	82	108	16	19	23
10	61	81	108	15	18	22
11	60	80	108	14	17	21
12	59	80	108	14	17	21
13	58	79	107	13	16	20
14	56	77	106	12	15	20
15	54	74	103	12	14	19
16	51	71	99	11	14	18

\* beats per minute \*\* breathing rate per minute

**Table 6.4: UK children, heart rate and respiratory rate by one-year age group (2.5, 50 & 97.5 centiles). n=1109**

The observed means and SDs with the fitted equations are shown in **figures 6.4 and 6.5**.

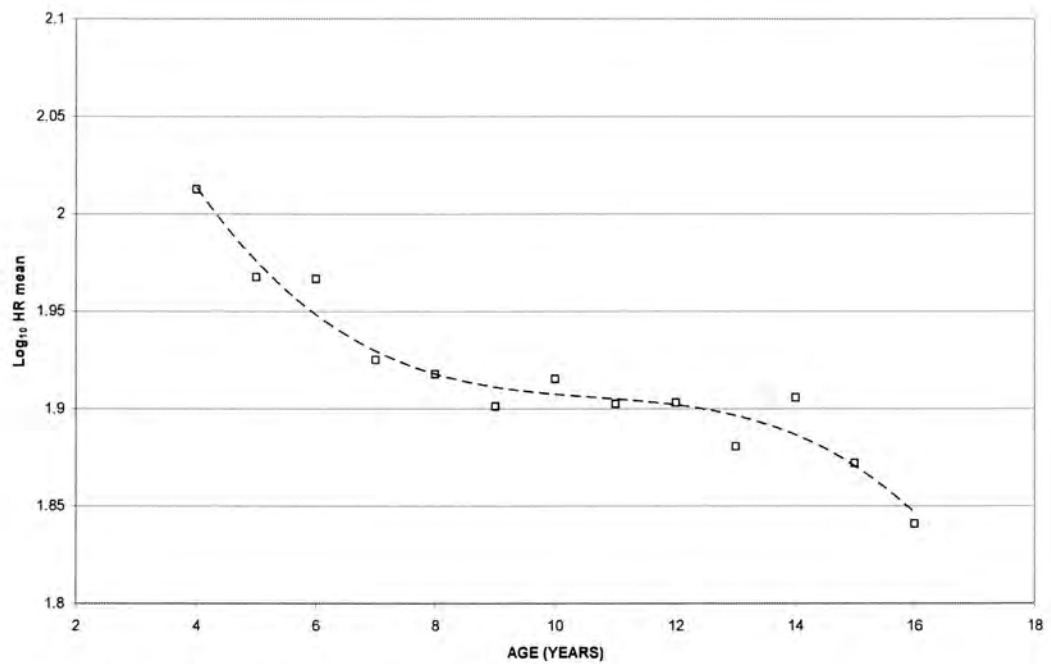


Figure 6.4: Log<sub>10</sub> (heart rate mean) against age

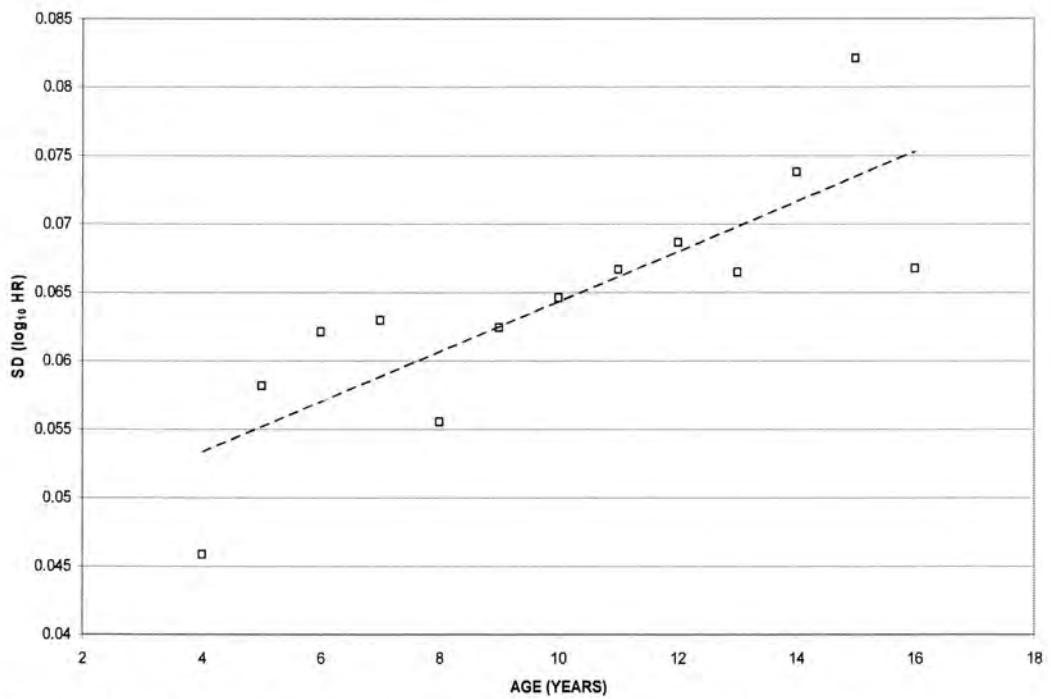
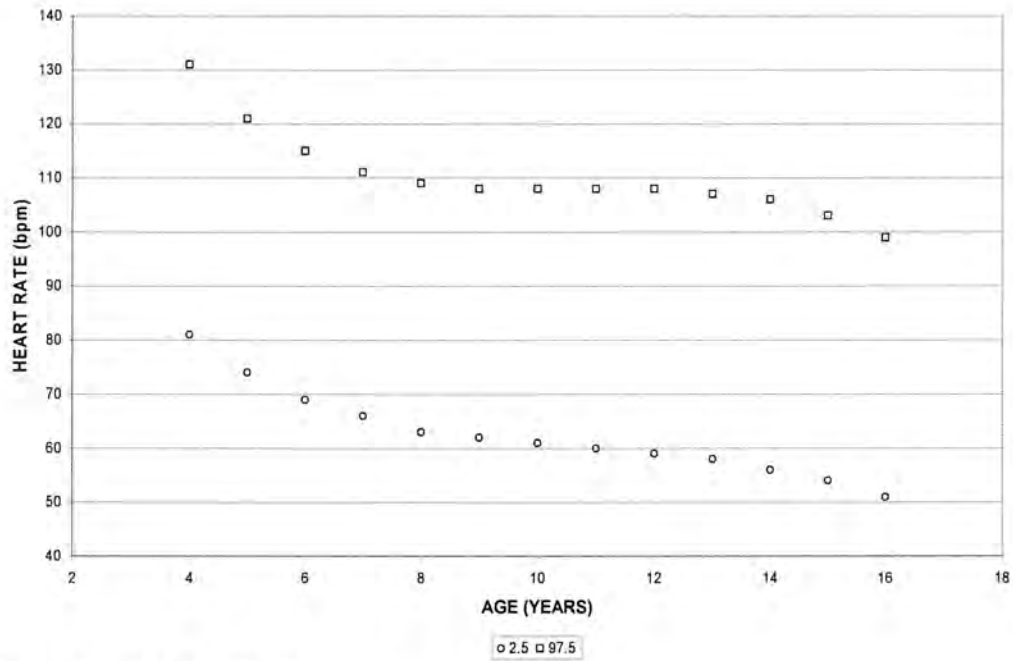


Figure 6.5: Standard deviation (SD) log<sub>10</sub> (heart rate) against age

If required, HR can be expressed as a z-score in the usual way by calculating  $(\log_{10}(\text{HR}) - \text{mean}) / \text{SD}$ . The HR values with fitted equations for HR ranges are shown in **figure 6.6**.



bpm = beats per minute

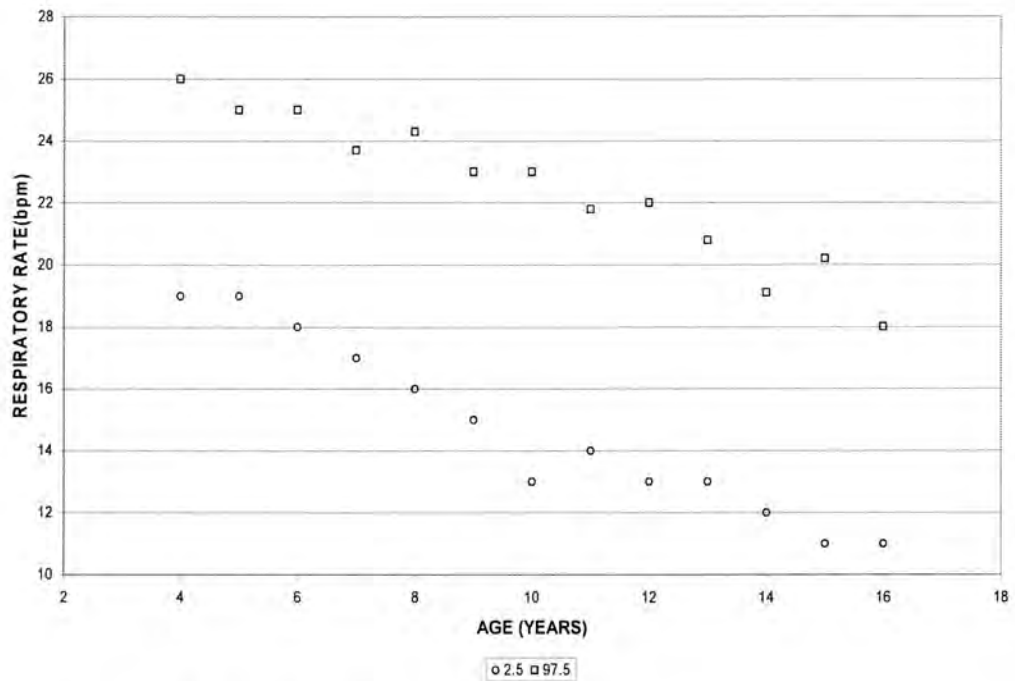
**Figure 6.6: UK children, heart rate against age (2½, 97½ centiles). n=1109**

### 6-3-3c: Respiratory Rate

The RR distributions were more irregular in shape, especially at the older ages where a ‘floor’ effect at 10-11 bpm was evident. The empirical 2.5 and 97.5 centiles were calculated and smoothed by linear fits. The fitted equations for the 2.5 and 97.5 centiles of RR were:

- 2½ centile =  $21.95 - 0.7239 \times \text{age}$
- 97½ centile =  $28.56 - 0.6051 \times \text{age}$

The observed values are shown at **table 6.4**, and the values and fitted equations for RR ranges are shown in **figure 6.7**. The values are shown as integers, rounded towards the median, with 95% reference interval ( $2\frac{1}{2}$ ,  $97\frac{1}{2}$  centiles).



bpm = breaths per minute

**Figure 6.7: UK children, respiratory rate against age ( $2\frac{1}{2}$ ,  $97\frac{1}{2}$  centiles). n=1109**

### 6-3-4: Other Data

#### 6-3-4a: Ambient Temperature

The ambient temperature range was 15.9 to 21.9 degrees Celsius, with a mean of 19.5C.

### 6-3-4b: Peripheral Cutaneous Oxygen Saturations

All measurements were 92% or above: only two were less than 93%. There was no clear relationship between age, height or weight and peripheral cutaneous oxygen saturation. The mean and median values along with range and Inter Quartile Range (IQR) are presented in **table 6.5**.

	% oxygen (95% CI)
Mean	98.4 (98.3,98.5)
Median	98.8 (98.7,98.9)
Range	92.4-100
IQR	97.9 - 99.2

**Table 6.5: UK children, Oxygen saturations. n=1109**

### 6-3-4c: Capillary Refill Time

All values were two seconds or less, with the exception of one child who had a CRT of three seconds.

## 6-4: Discussion

### 6-4-1: Sample size

The guidelines of Royston (Royston, 1991) were used. For a 95% reference range a sample size of at least 40 is desirable to avoid extrapolation, although a much larger sample size is desirable. The smallest sample size of this study was 49; the largest was 162 (mean 85). Limiting the standard error of the limits of the reference range to 10% of the standard deviation of the reference variable (at each one year age group) would require an overall sample size of 293, and limiting it to 5%, a total

sample size of 1169. The achieved sample size was 1109, producing a sample with a standard error of just over 5%.

#### **6-4-2: Measurement technique**

With regard to measurement of the physiological parameters, the method that was chosen was the one that most closely reflects day-to-day clinical practice. As RR is known to vary with the state of the patient (awake – quiet or active – or asleep) (Richards et al, 1984; Hoppenbrouwers et al, 1978), and HR is assumed to follow similar variability, the decision was made to assess each child after several minutes of sitting quietly at rest.

#### **6-4-2a: Respiratory Rate**

Some authors have suggested that the most accurate way of recording RR is through the use of machinery such as a pneumogram (Marks et al, 1995). Whilst this is likely to be highly accurate, it is unwieldy and impractical, and clearly does not reflect day-to-day clinical practice. Furthermore, there is good evidence that the application of machinery to the child produces an increase in the RR (Gilbert et al, 1972). This idea was therefore discounted.

The RR was measured by 60 seconds of direct observation of the clothed chest wall. The time period chosen has been shown to be accurate (Simoes et al, 1991; Clancy and Williams, 1991), and is recommended by many sources, including *Bates guide to physical examination and history taking* (Bickley and Hockleman, 1999) and the World Health Organisation (World Health Organisation, 1990).

Simoes *et al* (Simoes et al, 1991) showed that direct observation provides an



accurate measurement of paediatric RR: they found a mean of 1.79 breaths per minute variation from the values recorded by pneumogram. Rusconi *et al* (Rusconi et al, 1994) compared direct observation for 60 seconds with auscultation by stethoscope for the same time period. They found that the observed rate was a mean 1.8-2.6 breaths per minute lower than the auscultated rate. However, most practitioners routinely undertake RR measurement by direct observation, not auscultation, and so this method was employed in this study. Previous data have shown this method to be accurately repeatable (Rusconi et al, 1994).

#### **6-4-2b: Heart Rate**

In everyday practice, two methods are used to measure HR. The first is direct palpation of the radial artery at the wrist, a method that is widely practiced throughout the country. The second method commonly employed is through electronic means of recording HR: this is now standard practice in EDs and wards (although not as common in primary care settings). The HR is often recorded at the same time as blood pressure and SaO<sub>2</sub> using a monitor. Previous research has shown that the rate recorded by this method correlates very closely with that recorded at the radial artery at the same time (Hwu et al, 2000). There is also evidence that clinically recorded measurements, from direct pulse palpation or auscultation, suffer from counting errors (Hargest, 1974).

Sixty seconds was chosen as the duration of recording as this has been shown to be more accurate than either 15 or 30 second periods (Hollerbach and Sneed, 1990) (although the author of this paper suggested a 30 second measurement period

for a trade off between increased accuracy and improved time efficiency in clinical settings).

There is good evidence that applying machinery to record RR alters the recorded rate (Gilbert et al, 1972): there is no evidence of the presence or magnitude of a similar effect on HR. Although it is logical to extrapolate from Gilbert's work that an effect may be expected with regard to HR, there is a significant difference between the use of a device applied tightly to the face, and an oxygen saturation probe applied to the finger. Electronic means (using a Datex S5 Lite® monitor) were chosen to record this parameter, for ease of measurement, reliability, accuracy and clinical relevance.

### **6-4-3: Bias**

#### **6-4-3a: Intraobserver and Interobserver Variation**

Some of the previous studies that have looked at HR and RR have made calculations of the degree of variability in recordings (Rusconi et al, 1994; Simoes et al, 1991). This is usually attributed to interobserver variability. It is accepted as a weakness of this study, however, that there was no assessment of reliability or repeatability to quantify variation in recorded measurements (intraobserver variability), or use of more than one observer (interobserver variability).

#### **6-4-3b: Selection Bias**

Of 1153 children who agreed to participate in the study, 44 did not attend the sessions: they either did not want to take part at the last minute (28), were not at

school on the day in question due to illness (nine) or had other reasons (seven). It is accepted that children with chronic illness may have been deliberately withheld from the study, although what magnitude of effect this would have on the results (if any) is unclear.

No attempt was made to identify those children with minor illness on the day of study: the fact that they were well enough to attend school should allow them to be considered as part of a normal, healthy population. Marks *et al* identified children with upper respiratory infections in their study, and found that although up to 49% of their patients had minor respiratory symptoms (most of their subjects were in childcare centres and kindergartens) this had no apparent effect on the RR (Marks *et al*, 1993).

#### **6-4-4: The Reference Ranges**

The data are presented as whole integers rounded towards the median, and shown graphically (to illustrate the relationship with age) and in table form (for simplicity of reference) as median and 95% reference interval. These values are significantly different from the values quoted in some common texts: however, even where quoted values approximate to those measured here, they are without an evidence base to support them. This chapter provides evidence based reference ranges of HR and RR in healthy children, for day to day clinical use throughout the United Kingdom.

There are no data provided on children aged under four years, and there is a need for such ranges to be determined. Rusconi *et al* (Rusconi *et al*, 1994) produced RR data on children aged up to three years (although there are no data on HR in this

age group): their data are combined with the reference ranges from this study in **table 6.6** (only the awake data from Rusconi's work have been included, to reflect the arousal status of the children in this study. Children when asleep have different physiological values (Rusconi et al, 1994; Gagliardi and Rusconi, 1997)).

Age (years)	Respiratory Rate			APLS range	Actual range	Suggested range
	2½	50	97½			
<1*	22	42	61	40-60	22-61	25-60
1*	21	38	54	30-50	21-54	20-55
2*	22	32	41	25-30	19-36	20-40
3*	19	28	36			
4	20	22	26			
5	19	21	25			
6	18	21	24	20-25	14-24	15-25
7	17	20	24			
8	17	19	23			
9	16	19	23			
10	15	18	22			
11	14	17	21			
12	14	17	21	15-20	11-21	10-20
13	13	16	20			
14	12	15	20			
15	12	14	19			
16	11	14	18			

\* data from Rusconi

- APLS range – quoted in standard text (Advanced Life Support Group, 2005)
- Actual range – 2.5-97.5 centile limits for APLS age group (<1 / 1-2 / 2-5 / 5-12 / over 12 years)
- Suggested range – upper and lower limits by APLS age groups

**Table 6.6: Respiration rates by age – measured (2½, 50, 97½ centile), APLS ranges, and suggested ranges**

Tables 6.6 and 6.7 present HR ranges and combined RR ranges in comparison with those taught worldwide on APLS courses (Advanced Life Support Group, 2005). The suggested ranges to be taught on such paediatric courses have been rounded for ease of commitment to memory. For HR, values below five years

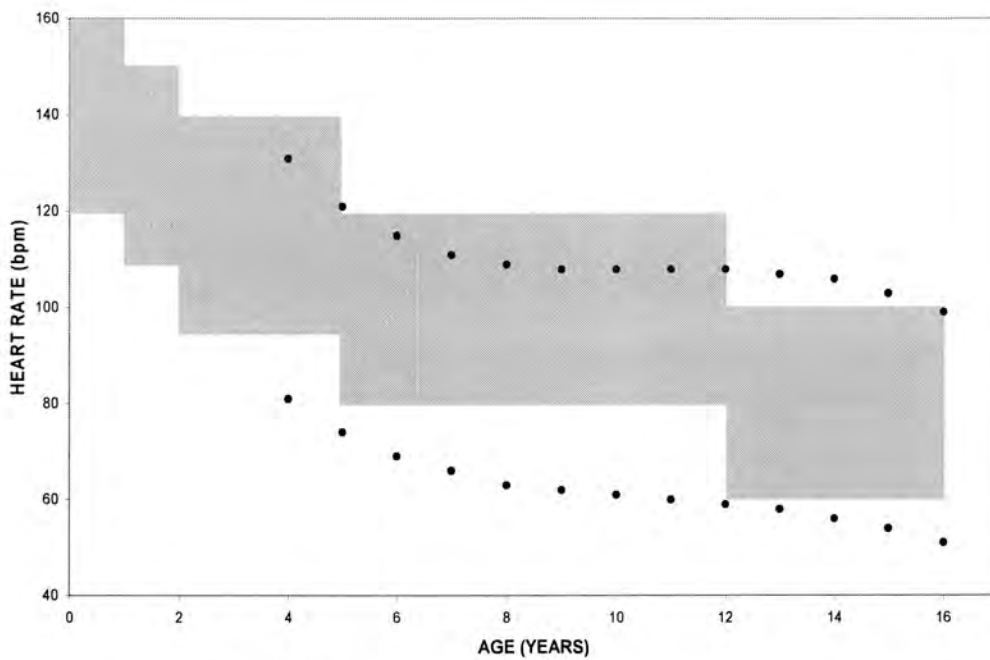
of age have remained unchanged as there is no evidence in this group (with the exception of the lower limit of HR in the two to five year age group, which has been adjusted to 75 bpm). These ranges are illustrated at **figures 6.8** and **6.9**.

Age (years)	Heart Rate			APLS range	Actual range	Suggested range
	2½	50	97½			
<1	*	*	*	120-160		120-160
1	*	*	*	110-150		110-150
2	*	*	*			
3	*	*	*			
4	81	103	131	95-140	74-	75-140
5	74	95	121			
6	69	89	115			
7	66	85	111			
8	63	83	109	80-120	60-115	60-115
9	62	82	108			
10	61	81	108			
11	60	80	108			
12	59	80	108			
13	58	79	107			
14	56	77	106	60-100	51-108	50-110
15	54	74	103			
16	51	71	99			

\* no data

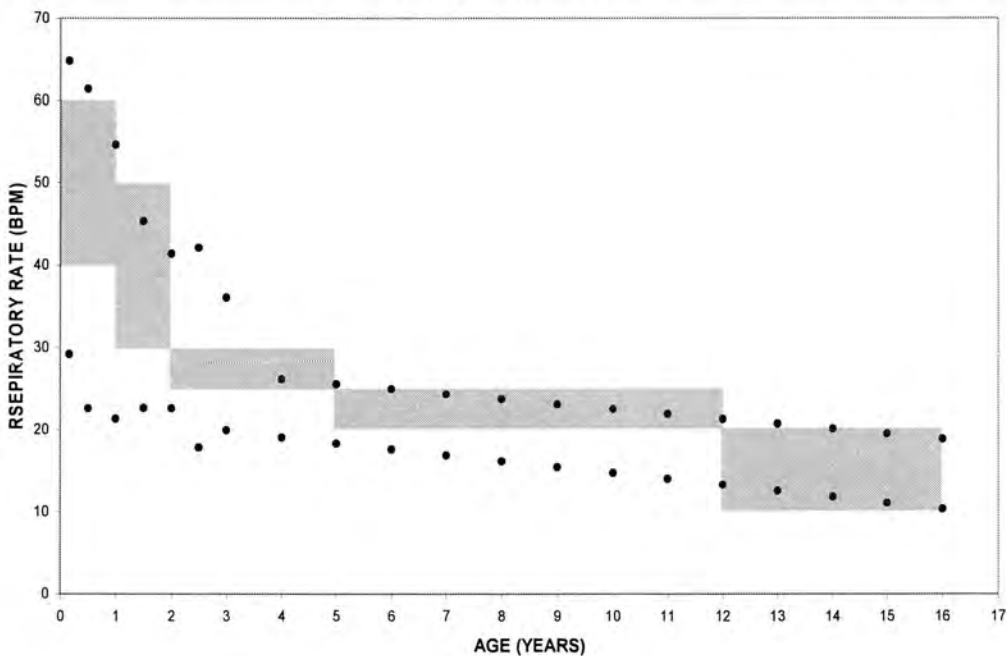
- APLS range – quoted in standard text (Advanced Life Support Group, 2005)
- Actual range – 2.5-97.5 centile limits for APLS age group (<1 / 1-2 / 2-5 / 5-12 / over 12 years)
- Suggested range – upper and lower limits by APLS age groups (age 2 years added as a new age group)

**Table 6.7: Heart rates by age – measured (2½, 50, 97½ centile), APLS ranges, and suggested ranges**



bpm — beats per minute

**Figure 6.8: UK heart rate (2½, 97½ centiles) and APLS ranges (shaded)**



bpm — breathes per minute

**Figure 6.9: UK respiratory rate (2½, 97½ centiles) and APLS ranges (shaded) (contains data from Rusconi (Rusconi et al, 1994))**

#### **6-4-5: Height and Weight**

The height and weight data were analysed separately for the sexes, and plotted against the standard UK growth reference charts (UK 90) (Freeman et al, 1995). For both sexes, height and weight fitted neatly between the 50<sup>th</sup> and 75<sup>th</sup> centiles. No further statistical analysis was undertaken as the intention of this measurement was not to derive Standard Deviation Scores (the recommended method of determining epidemiologically whether a population is growing in line with the growth charts (Rudolf et al, 2004; Saxena et al, 2004; Rudolf et al, 2000)), but rather to establish whether the study population could be considered representative of a “typical” UK school population. Although the study group plotted slightly above the UK 90 medians, this is not significantly different and the sample may be considered representative.

The correlation of HR and RR with height and weight was very poor, and in a negative direction. The tendency towards negative values may reflect the negative trend of HR and RR (as against the positive trend of height and weight) with increasing age. There appears to be no case for considering height and weight in assessing HR and RR.

#### **6-4-6: Other Data**

##### **6-4-6a: Ambient Temperature**

There were insufficient data regarding the variation in temperature to make any reliable conclusions about the effect of this variable on the recorded parameters.

#### **6-4-6b: Peripheral Cutaneous Oxygen Saturations**

A peripheral cutaneous oxygen saturation of between 90 – 93% is generally accepted as the lower end of normal (Marcus et al, 1992; Mok et al, 1986). In this study there were two children with SaO<sub>2</sub> below 93%: both of these had values of 92%. Neither child had any symptoms, and both had appropriate waveforms.

These data are in keeping with previous work, and suggest that 92% can be considered the lower end of normal peripheral cutaneous oxygen saturations in healthy children. There was no effect of gender on the results.

#### **6-4-6c: Capillary Refill Time**

All CRT recordings (except one) were two seconds or less, in keeping with the accepted range of this centrally recorded measurement in children (peripheral CRT is known to follow a more bell shaped distribution) (Bumke and Maconochie, 2001).

#### **6-5: Summary**

- This chapter has established reference ranges for healthy, resting children who may be considered typical of children in the UK. Reference ranges with 2.5 and 97.5 centiles have been derived which can be used as norms for everyday clinical use.
- There was no relationship between height or weight and the physiological measures.
- These reference values have been summarised into simple to remember ranges for Life Support courses such as the APLS



(Advanced Life Support Group, 2005) and ATLS (American College of Surgeons, 2005). Furthermore, these ranges may be used to establish whether other sample populations (such as South African children) have similar physiological values.

**CHAPTER 7:**  
**REFERENCE RANGES OF HEART AND RESPIRATORY RATE**  
**– SOUTH AFRICA**

- 7-1: Introduction
- 7-2: Methods
  - 7-2-1: Choice of School
  - 7-2-2: Consent
  - 7-2-3: Data Collection
  - 7-2-4: Data Analysis
- 7-3: Results
- 7-4: Discussion
  - 7-4-1: Demographics
  - 7-4-2: Height and Weight
  - 7-4-3: Physiological Ranges
- 7-5: Summary

## **7-1: Introduction**

The difficulties in determining the extent of the relationship between growth in the UK and in the developing world have been presented (**Chapter 5**). There are no data concerning this relationship with South African children, who have been identified as suffering from a high incidence of malnutrition and chronic illness.

The purpose of this chapter is to determine the range of RR and HR in a population of South African children, and to establish whether these differ from those values derived for the UK.

## **7-2: Methods**

Ethical approval was gained through the Ethics Board at the University of Cape Town (UCT).

### **7-2-1: Choice of School**

The majority of patients seen in the RXH Trauma Unit come from the Cape Flats area of the city: the townships. The vast majority of these children are Black or Coloured in ethnic origin. In view of this demographic information, a school in the townships was chosen as this would reflect the ethnic and socio-economic status of RXH patients.

The Chris Hani Memorial School is situated in Langa, a predominantly black area. It is charity funded and educates children who have not had their birth registered and therefore are unable to enter the state school system. It educates children from five to 16 years of age, and approximately 80% of its learners are black.

### **7-2-2: Consent**

The head teacher was contacted by letter and then in a face-to-face meeting. The intention of the project was explained and the proposal was then taken to all of the teachers at the school: there were no concerns raised. The proposal was then presented to the children in an assembly and to their parents in a letter home from the school. No objections were raised.

It was the opinion of the Ethics Board at UCT that consent was not required.

### **7-2-3: Data Collection**

All children were seen in their school by the author, in the presence of a female nurse chaperone, in May 2002. Children were brought out of their classrooms and left to sit quietly outside the study room for five minutes.

The child then sat quietly in a warm, well lit classroom while their RR was measured by 60 seconds direct observation of the clothed chest wall by the author. They then had their HR measured for 60 seconds using a Datex S5 Lite® monitor. A finger probe was used in all cases. Recording did not commence until a suitable trace with a regular, pulsatile waveform was achieved continuously for 20 seconds. Data was transferred real time to a computer, using Datex software: recordings were made at 5-second intervals for 60 seconds. The mean of these recordings was registered as the child's HR.

CRT was measured by direct pressure on the child's forehead. A calibrated stopwatch was used to time the five seconds of pressure and the time to return of normal skin colour.

Children then had their standing height recorded using a Leicester height meter, and weight using scales calibrated by the department of medical physics at the Red Cross Children's Hospital. All equipment was the same as had been used in the UK.

Children who were unwell on the day of the study (but were well enough to attend school) were still included in the sample, as were children with diagnosed or undiagnosed medical conditions. No attempt was made to identify these children in the database.

#### **7-2-4: Data Analysis**

The heights and weights of the children were plotted on the UK 90 growth charts (Freeman et al, 1995), to determine whether they could be considered to be identical to a UK population. Each plot was at the mid point of that year on the centile chart (i.e. the median weight for six year olds was plotted at 6.5 years on the chart).

The recorded RR and HR were analysed with Microsoft Excel® software. Medians were derived and plotted against the reference ranges derived in the UK. Age was considered to be age in years at the last birthday. The data were therefore considered as 12 separate frequency distributions, from five to 16 years (the four year old age group in the UK were ignored for these analyses). Two way analysis of variance was undertaken to determine any difference in the mean values of each of these parameters between the two countries.

### 7-3: Results

#### 7-3-1: Demographics

The Chris Hani Memorial School in Langa educates 392 pupils: all children who were present on the days of data collection took part in the study – a total of 346 (88%). The spread of ages is shown in **table 7.1**: age ranged from five to 16 years.

Age (years)	Male	Female	Total (%)
5	15	13	28 (8.1)
6	21	20	41 (11.9)
7	9	15	24 (6.9)
8	12	12	24 (6.9)
9	6	14	20 (5.8)
10	13	10	23 (6.7)
11	22	16	38 (11.0)
12	13	13	26 (7.5)
13	16	13	29 (8.4)
14	16	17	33 (9.5)
15	8	20	28 (8.1)
16	13	19	32 (9.3)
	<b>164</b>	<b>182</b>	

**TABLE 7.1: age and sex distribution, SA children. n=346**

One hundred and eighty two were female (52.6%). The age ranges and means are in **table 7.2**. The smallest group was the nine year olds, with 20, and there were 41 six year olds.

	Male	Female	Total
Range	6-22	10-20	20-41
Mean	13.7	15.2	28.8
Median	13	14.5	29

**TABLE 7.2: SA children, group size data - range, mean and median in each one-year age group. n=346**

### 7-3-2: Height and Weight

The data were plotted by sex onto UK 90 growth charts, for height and weight. Height was plotted as mean value, and weight as median. The height and weight of both sexes plotted between the 25<sup>th</sup> and 50<sup>th</sup> centiles, with a small degree of crossing over. In girls, this occurred towards the older children, with 15 and 16 year olds approaching the 75<sup>th</sup> centile for height and weight. Boys demonstrated similar curves, but at a slightly lower level: for weight, they tracked towards the 25<sup>th</sup> centile until the older age group, where 14 to 16 year olds touched the 50<sup>th</sup> centile. For height, boys were slightly smaller than girls, plotting close to the 25<sup>th</sup> centile throughout all ages. Both sexes in the UK plotted between the 50<sup>th</sup> and 75<sup>th</sup> centiles (for height and weight, with girls being slightly taller and heavier).

As both samples plot neatly onto the UK 90 charts, they may be considered similar enough by height and weight to undertake further physiological analysis between the two groups.

### 7-3-3: Physiological Ranges

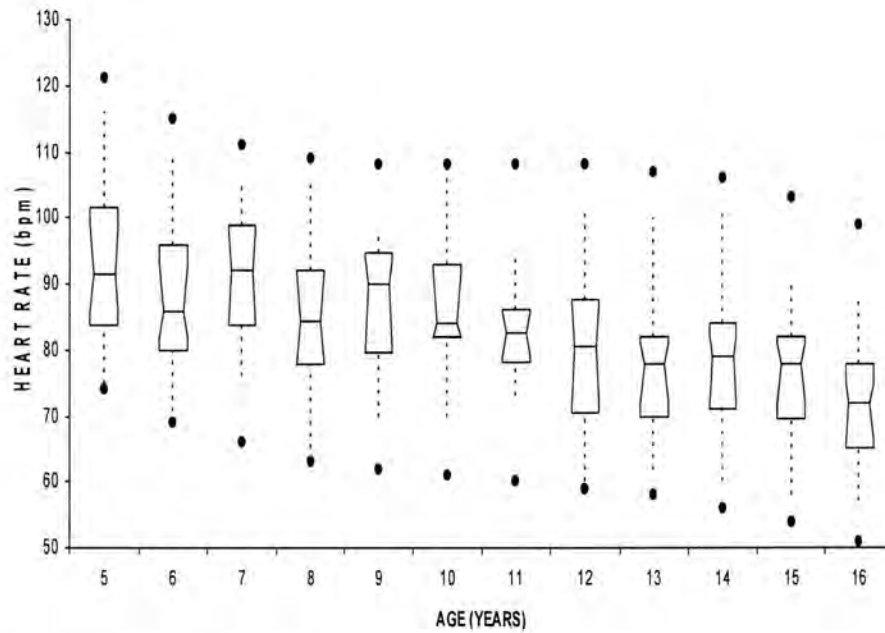
The median HR and RR are presented at **table 7.3**. They are plotted (with IQR) against UK reference ranges in **figures 7.1** and **7.2**.

Two way analysis of variance was undertaken, and showed that there was no significant difference between the groups by HR ( $p=0.286$ ). With regard to RR, there was a significant difference with the SA children having a mean 0.42 breaths per minute higher RR than their UK counterparts ( $p<0.0005$ ) – this difference was minimal under age 10, and almost 0.9 bpm after age 10 years. All CRT measurements were two seconds or less.

Age (years)	HR (bpm)*	RR (bpm)**
5	91	22
6	86	22
7	92	21
8	84	20
9	90	19
10	84	18
11	82	19
12	80	17
13	78	17
14	79	16
15	78	16
16	72	15

\* beats per minute  
 \*\* breaths per minutes

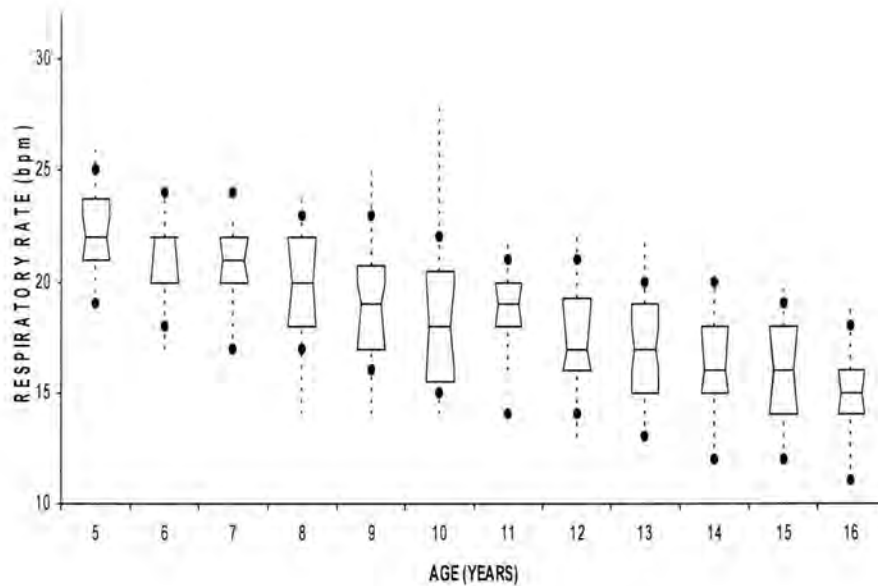
**TABLE 7.3: SA children, heart and respiratory rate medians. n=346**



bpm = beats per minute

**Figure 7.1: Heart rate against age: SA median, IQR and range against UK reference range (2½, 97½ centiles(•))**





bpm = breaths per minute

**Figure 7.2: Respiratory rate against age: SA median, IQR and range on UK reference range (2½, 97½ centiles (•))**

#### 7-4: Discussion

The population of South African children attending township schools such as the Chris Hani memorial school in Langa may be expected to be smaller and less heavy than their UK counterparts, due to the high incidence of malnutrition and chronic diseases (including HIV / AIDS). This was indeed found to be the case, measuring around one quartile lighter and smaller than their UK peers. However, they still plotted well inside the reference ranges for UK children (UK 90 growth charts) and it is reasonable, therefore, to treat them as similar populations.

Whether this would apply to different social classes of children in South Africa is not proven by this study: wealthier, healthier children would be expected to plot closer to the UK reference ranges than this socially disadvantaged group. This is

in keeping with the growth patterns of ethnic minorities inside and outside their native countries, as discussed in **Chapter 5**.

With regard to HR and RR, the decrease in both values with increasing age has been well established by this thesis and other authors (Rusconi et al, 1994; Gagliardi and Rusconi, 1997). The relationship with body mass in some animals has been discussed (**Chapter 5**): similar relationships were expected in the study populations in both the UK and SA arms of this thesis, but were not demonstrated in the UK study. Further comparisons by height and weight were therefore not undertaken for the SA sample. The only HR and RR comparisons were by age.

The two way analysis of variance calculations proved statistically what is evident on **figures 7.1** and **7.2**. For RR (**table 7.4**), a significant difference exists with the SA children having a mean 0.42 breaths per minute higher RR than the UK group (becoming most apparent after 10 years of age) ( $p=0.0001$ ). This difference is statistically, but not clinically, significant: measurement of less than one breath per minute is not possible and, pragmatically, the two groups may be considered to have identical RR. For HR (**table 7.5**), there is no difference in the SA and UK populations overall (there are up to four beat per minute differences at the extremes of age, but in opposite directions) ( $p=0.286$ ).

Source	Type III sum of squares	df	Mean square	F	p
Intercept	488171.661	25	19626.826	4088.137	0.0001
Age	6372.754	12	531.063	111.183	0.0001
Country	85.488	1	85.488	17.898	0.0001
Age* country	65.534	11	5.776	1.209	0.275

df - degrees of freedom

**Table 7.4: two way analysis of variation, respiratory rate**

Source	Type III Sum of Squares	df	Mean Square	F	p
Intercept	6927241.002	1	6927241.002	1583.122	.0001
Age	56665.102	12	4722.092	17.899	.0001
Country	323.396	1	323.396	1.251	.286
Age* country	2881.848	11	261.986	1.799	.049

df - degrees of freedom

**Table 7.5: Two way analysis of variance, heart rate**

### 7-5: Summary

- This chapter has addressed one of the core issues underpinning the validation of the PTT: whether the study population at RXH and that studied in the UK may be considered to have the same range of RR and HR. As attendees at the Trauma Unit at RXH are injured and may be expected to have different physiology, a normal South African population was studied to make this comparison. The majority of attendees at RXH are from identical disadvantaged communities to the children at the Chris Hani school and the results of this study are extrapolated as being applicable to that group.

- There were no clinically significant differences in HR or RR between the two study populations, despite the South African children being smaller and lighter.

## CHAPTER 8:

### DELPHI STUDY INTO TRIAGE ALGORITHM VALIDATION

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- 8-2: History of the Delphi Method
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## **8-1: Introduction**

The purpose of this chapter is to consider the use of Delphi methodology as a research tool, and describe the undertaking of such a study as a means of deriving a resource-requirement based outcome measure for validation of primary triage tools.

## **8-2: History of the Delphi Method**

Use of the term Delphi derives from the ancient Greek Delphic oracles' skills of interpretation and foresight (Linstone and Turoff, 1975). As a technique, the Delphi study was developed in the 1950s by the RAND Corporation in California, USA (Dalkey and Helmer, 1963): the procedure was designed to obtain the most reliable consensus of a group of experts by a series of questionnaires interspersed with controlled feedback. It was originally developed as a method for predicting future events by consulting panels of experts in the particular field of interest (typically science and technology). In recent years the technique has found a much wider applicability in the more mainstream social sciences, in business and, very recently, it has become a more commonly used technique within the fields of medicine and nursing (Jones and Hunter, 1995).

The Delphi technique is a consensus research method designed to harness the insights of appropriate experts in a particular field to enable decisions to be made in areas where published information is inadequate or nonexistent (Pill, 1971). In areas such as these, where expertise may be widespread and represented across a wide spectrum of specialities and interests, more traditional methods such as committee meetings and conferences may be impractical due to time and geographical constraints (Preble, 1983).

The reasons for using Delphi methodology were summarised as:

“when working in conditions of insufficient data, uncertainty, incomplete theory and a high order of complexity, there are two possible options. We can wait until sufficient information becomes available to formulate an adequate theory capable of explaining the problem or we can make the most of an admittedly unsatisfactory position and try to obtain the relevant intuitive insights of experts and use their judgements as systematically as possible. The use of the Delphi approach represents an effort to proceed along the latter of these options” (Pill, 1971).

Many variants of the Delphi have been described, and its broad application led to new definitions:

“Delphi may be characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” (Linsotne and Turoff, 1975).

### **8-3: Appropriateness of Delphi for this Study**

The limitations in the currently accepted methods of validating triage algorithms have been presented (**Chapter 4**). It is apparent that validation in the setting of a major incident is not going to occur, for practical and ethical reasons. The work of both Baxt (Baxt and Upenieks, 1990) and Garner (Garner et al, 2001) is helpful in establishing more robust mechanisms for such validation: however, the findings of both studies are still only applicable to distinguishing between those patients who are T1 and those who are not-T1. There is currently no accepted method of determining ability to distinguish T2 and T3 patients from T1.

In situations such as major incidents where formal experimentation or trials are impossible, other techniques such as computer modelling or simulations may be used to reach a conclusion. However, in complex situations modelling may be

impossible or too complex to perform as there is a vast array of external factors to take into account.

The use of expert derived criteria has stood the test of publication in peer reviewed journals, and this work can be developed through more rigorous methods incorporating the views of a wide range of experts in the fields of major incident management and care of injured paediatric patients.

This Delphi study was used to formulate a series of criteria against which a paediatric major incident primary triage algorithm might be more appropriately validated. This requires the input of a group of experts in fields relevant to the management of children in major incidents. There are several methods available to generate group responses.

#### **8-4: Group Research Techniques**

One long accepted means for dealing with complicated problems such as these has been to use committee meetings or steering groups to reach a group consensus or to formulate guidelines (Jones and Hunter, 1995; Whitman, 1990a). Assembling a group of interested and relevant individuals to a single meeting or series of meetings may allow discussion of the issues and possibly lead to a conclusion: however, the outcome and usefulness of committees is influenced by the interpersonal interactions within the group (Goodman, 1987). The conclusions gained from the group may be strongly influenced by those members with dominant personalities imposing their views on the other “weaker” members. In addition, those in positions of responsibility may find it difficult to shift their position without “losing face” (Rauch, 1979). Committee meetings may work well where there is a



small degree of variance in opinion within the group, but where variance is high (and particularly when opinions conflict between groups and individuals) the value of the discussion and ultimately of the conclusions may be poor. In effect the results of a committee meeting may more closely reflect the individuals' personalities and private agendas than the problem in question (Maier, 1967).

The Nominal Group Method (Fink et al, 1984) is a variation on the committee process, and goes a long way towards resolving these problems through the weighting of certain members' opinions. This method would be suitable for this project if it were possible to have all members meet face to face: however, due to distance this was not possible. A technique that allowed exchange of ideas at a remote distance was therefore required.

The research method chosen had to:

- Allow discussion of views without the influence of personal status.
- Allow alteration of views without "loss of face".
- Involve all groups relating to the subject.
- Allow the combination of a number of estimates from individuals into a group response.

The Delphi method satisfies these points (Linstone and Turoff, 1975). There are many areas of health care research that are not amenable to the application of traditional quantitative research methods: where there is insufficient or contradictory information on a subject (or where clinical experimentation is impossible) clinical decision making may be extremely difficult, yet it may be just as important for

rational decisions to be made and implemented. Qualitative methods of research such as Delphi have been developed for use in such situations.

There are a few individuals with specialist knowledge in the planning and response to major incidents. However, they are geographically separated and represent a wide spectrum of interested specialities. To investigate the triage of children in major incidents it was necessary to gain the opinions and experience of these experts. The use of the Delphi technique was considered for this study due to the complex, multidisciplinary nature of the problem (Turoff, 1970), together with the diverse and geographically distant membership of the panel (Preble, 1983). The Delphi method offered the most feasible technique with which to progress in the validation of paediatric major incident triage algorithms.

#### **8-5: Basic structure of a Delphi study**

Delphi is designed to use the positive attributes of forming opinions through the use of large groups without the negative aspects of group work attributable to social difficulties within groups. The Delphi technique has four features: Anonymity, Iteration, Controlled feedback and Statistical aggregation of group response (Jones and Hunter, 1995).

**Anonymity** is achieved with postal (or, more commonly these days, electronic mail) questionnaires. By allowing group members to both consider and answer their replies privately, undue social pressures are avoided. This privacy allows members to express their views without the feelings of pressure that may be exerted by dominant individuals within a group. It also avoids the effect of “status” as an influencing factor within a multidisciplinary group. Anonymity also allows

members to change their opinions without fear of loss of face or agreement with an idea given by one of lower “perceived status” (Whitman, 1990b). In some versions of the Delphi, individuals may be identified by name or by post (Rauch, 1979), however in all versions the participants’ answers are anonymous, i.e. the individual’s answers are anonymous even if the participant is not.

**Iteration** occurs through the submission of a questionnaire over a series of rounds, allowing members to change their opinions with regard to the other members’ opinions.

**Controlled feedback** occurs between rounds as the results of each round are analysed by the researcher and the responses for each given statement are fed back to all members of the group. This allows members of the group to assess their views in the light of the group’s responses. The feedback may be presented in a number of ways and complexities, but is most often given as a mean, median or interquartile range. The nature of the feedback is dependant on what the answer required from the Delphi is. Delphis that are only trying to achieve consensus may simply give numerical responses (Turoff, 1970).

**Statistical group response** is obtained at the end of the procedure. This is an expression of the degree of consensus of the group on a particular issue. It is commonly expressed as a mean value and spread of opinion. The mean and the spread of opinion can be combined to show the “strength” of opinion. If required a measure can be made of the degree to which the respondents agree with the issue under consideration as well as the degree with which they agree with themselves.

## **8-6: Types of Delphi**

There are a number of different Delphi types available to be used: in all methods the four principles (listed above) are adhered to. However, several variants of the Delphi have been described to examine different types of questions. They all share similar practical execution and construction but they differ in their aim and concept.

### **8-6-1: The Classical Delphi**

This is the original design (as developed by the RAND organisation in the 1950s): it is used to create consensus and predict scientific conditions using a panel of anonymous experts (Linstone and Turoff, 1975). The Classical Delphi is a statistical process to enable the estimation of an answer through a process of analysing the estimates of a large number of anonymous participants. The Classical Delphi is used to gain a group opinion on forecast statements: it tries to develop consensus through the rounds of questionnaires by allowing participants to move their statements in light of the responses of the other members. Its usefulness has been borne out in many studies of prediction (in industry, science and more recently health care). By allowing respondents to change their mind in complete anonymity between rounds, undecided members tend to be attracted towards the results of the “true experts”(Linstone and Turoff, 1975; Rauch, 1979). In taking the average between all results at the end of the Delphi process an approximation towards the true answer may be found.

In health care the use of the Classical Delphi may be found in areas such as the assessment of future numbers of disease victims (Dalkey and Helmer, 1963) where an estimate of numbers is required.

### **8-6-2: The Policy Delphi**

The Policy Delphi uses a panel of lobbyists and referees to examine a policy issue (Turoff, 1970). The Policy Delphi defines “experts” as those who have an interest in the subject in question, or those who would be affected by the policy in question: “expert knowledge” is not a prerequisite for participation in the group if the participant is to be affected by the outcome of the study. The Policy Delphi allows all lobbyists to affect the structuring of decisions. Individual lobbyists, having a voice on the issue, are enabled to both present and influence their own and other’s views. It creates ideas around a subject.

In health care research the Policy Delphi could find many uses both at national and local levels. There are few policy decisions in medicine that do not affect more than one group of individuals. By seeking the views and concerns of all affected parties on policy decisions subsequent decisions and beyond that implementation will be more easily achieved. Policy Delphi studies have been used in health care to determine many policies such as research priorities.

### **8-6-3: The Decision Delphi**

The Decision Delphi is used to prepare, assist and make decisions (Rauch, 1979). In many organisations developments are often driven by the actions of a few decision makers in key positions rather than by the goals or desires of the affected

groups. Ultimate decisions are often strongly influenced by a long chain of detailed smaller decisions. The individual decisions are unimportant, but when combined they create the ultimate result. This is an inefficient and slow method of decision making. The Decision Delphi makes explicit all the issues related to the decision in question and by involving the key players in an organisation makes the decision making process more thorough and faster. Membership of a Decision Delphi group is not restricted to individuals in positions of power but it is essential that such individuals are strongly represented. Non-empowered experts may also be members of the group if their knowledge is essential to the decision making process.

The Decision Delphi is designed to create a decision where there was none before. By using the key players and gaining consensus between them, decisions may be carried out into practice rapidly as at the end of the process, not only has the decision been made by those with the expertise in the area in question but also by the individuals responsible for implementation of the decision. In the Decision Delphi, unlike the other forms, the panellists are known to each other but their responses and subsequent changes in opinion are not: anonymity of opinion is maintained whereas absolute anonymity is not. Its most effective applications are in fields that are amenable and willing to change.

#### **8-6-4: Selection of Delphi Design**

Elements of all the above types of Delphi were of use when designing the Delphi investigating the triage of children in major incidents. The Classical Delphi was the basis for the overall design, but with some elements of both the Decision Delphi and Policy Delphi.

## **8-7: Conduct of the Delphi**

A Delphi study is typically conducted in several stages:

- Selection of the “expert panel”
- The Delphi Rounds
  - The submissions, assessment and feedback of the Delphi questionnaires
- Final analysis and conclusions

### **8-7-1: Selection of the “Expert Panel”**

The Delphi uses an expert panel to gain views on the issue in question (Linstone and Turoff, 1975). However, the definition of what constitutes an expert varies, and different forms of the Delphi technique define expertise in different ways. An expert may be considered to be an individual who has recognised expertise in a particular subject, or may be someone who may be influenced by the outcome of the Delphi (Turoff, 1970).

In the earliest uses of the Delphi, expertise was not clearly defined and on occasion the use of “non-experts” revealed identical results to those of the acknowledged experts (Hill and Fowles, 1975). However, these studies have been criticised for poorly differentiating experts from non-experts (Rowe et al, 1991). In health care research identifying those with specific skills and / or experience related to aspects of the topic in question is often relatively easy: these individuals may be experts in their field but not in the overall subject in question (Rowe et al, 1991). In selecting members for the Delphi group those with skills relevant to the problem being discussed were considered as experts.

The selection of persons for participation in the Delphi process was conducted in 2002 by the author. This involved the identification of persons with established expertise in the field of major incidents in the UK and South Africa, and those who have expertise in the management of injured children. It was necessary to select panel members on the basis of published work in this field, involvement in paediatric major incident planning, or paediatric expertise.

Representation was therefore sought from the following organisations and individuals: -

- Ambulance Service
- Consultants in Emergency Medicine
- Major Incident Planners
- Paediatric Emergency Medicine Consultants
- Paediatric Specialists
- Immediate Care specialists
- Emergency nurses

**The Ambulance Services** play a key role in the response to a major incident. They are likely to be the first on the scene, and are usually tasked with triage of victims. Major incidents are one of the few times when predominantly hospital-based clinicians may be required to work in the pre-hospital environment but this must be in a complementary role (Welsh Affairs Committee Third Report, 1996). It is essential that the views of the Ambulance Service are represented in any triage system that they are to use, and this also applies to deriving validation tools for such systems.



A high priority was placed on obtaining senior views from the Ambulance Services, both in the UK and South Africa. Three were approached, and two agreed to participate:

Prof M Woolard                      Deputy Chief Ambulance Officer, Welsh Ambulance Service

Prof C MacFarlane                      Director, Gauteng Emergency Medical Services

**Consultants in Emergency Medicine:** major incidents will inevitably involve Emergency Departments. The views and experience of Emergency Medicine consultants who have responded to major incidents involving children in recent years, or have extensive experience in planning for such events, was sought. All consultants approached responded to the Delphi questionnaire. Their experience of dealing with large numbers of children within mixed departments (child & adult) may provide insight into the problems associated with such an event.

Five consultants were approached; the following four agreed to participate:

Dr S Carley                              Emergency Medicine, Manchester

Mr J Wyatt                              Emergency Medicine, Truro

Lt Col T Hodgetts RAMC                      Emergency Medicine, Defence Medical Services

Dr B Bonner                              Emergency Medicine, Cape Town

**Consultants in Paediatric Emergency Medicine:** as the objective of this Delphi study was concerned with triage of children in major incidents, it was felt essential to have representation from consultants in paediatric emergency medicine. Both consultants who were approached agreed to take part in the study:

Dr I Maconochie                      Paediatric Emergency Medicine, London

Dr AB Van As                         Paediatric Emergency Medicine, Cape Town

**Paediatric Specialists:** Paediatric Emergency medicine consultants, although experts in the treatment of children in the emergency department, may not fully appreciate the impact of a major incident on in-hospital and specialist resources. The views of paediatric clinicians and sub-specialists were therefore sought. In addition many major incident plans cite the inclusion of a general paediatrician in the resuscitation teams in a major incident involving children. Resources such as ICU and specialist anaesthesia are generally in short supply. The views of high profile individuals in the field was therefore sought to identify the best way in which to use these resources. All six agreed:

Dr L Heyns                             Paediatric Intensive Care, Cape Town

Prof A Argent                         Paediatric Intensive Care, Cape Town

Prof K Boffard                        Trauma Surgery, Johannesburg

Prof H Rode                            Paediatric Surgery, Cape Town

Prof S Thomson                       Paediatric Surgery, Durban

Dr S Smith                             Paediatrics, Nottingham

**Immediate Care** is now recognised as a separate speciality and has recently acquired its own faculty at the Royal College of Surgeons of Edinburgh. Its members have experience with the delivery of advanced life support in the pre-hospital environment. In addition they are trained in the management of major incidents and can take the role of the Medical Commander. Their experience and training is essential for consideration of management in the pre-hospital environment.

Two were approached and agreed to participate:

Dr H Guly	Emergency Medicine / Immediate Care, Plymouth
Lt Col I Greaves RAMC	Emergency Medicine / Immediate Care, Defence Medical Services

**Emergency Nurses** play a critical role in the hospital management of paediatric major incidents. They are typically very experienced at day-to-day triage of children, although in a major incident setting this role typically passes to one of the senior Emergency Physicians. Two nurses were approached to participate; one agreed but failed to complete round one despite numerous contacts and prompts. Although nursing input would have been valued for this study, as nurses do not typically undertake major incident triage and as this study was aimed at validation of a tool rather than its practical application, the absence of nursing input was not felt to have compromised the results.

### **8-7-1a: Results of Stage One**

Twenty individuals were approached for round one. Of these, four did not complete the first round (either not agreeing to participate, or not returning the necessary responses), leaving 16 to undertake the study.

One of the keys of the Policy Delphi is the concept of including the “consumer” (Turoff, 1970) – the views of the individuals affected by the implementation of the policy decisions should be included in the group discussion process. For this project, the consumers could be considered to be the children injured in the major incident: clearly, obtaining their input is not a realistic option. An alternative view may be that the consumers are the people using the triage algorithms, in which case these groups have been well represented in the Delphi panel and the need for consumer representation may be considered to have been satisfied.

The selection of experts in a Delphi process represents the potential for a considerable degree of bias. It might have been possible to select only those individuals who held similar or the same views to the researcher or project supervisor. This would have been a serious flaw in the design of the Delphi. Effort was made to avoid this by selecting members based on position or profile within their respective organisations. Consideration as to what the members’ views actually were was not made at this stage.

### **8-7-2: The Delphi Rounds**

Once the selection of the Delphi group members had been completed the process of the Delphi rounds began. In Delphi there is no agreed standard method of

design or analysis of Delphi rounds (Linstone and Turoff, 1975). However, the format of the rounds as described below is fairly typical.

### **8-7-2a: Round One**

In a Classical Delphi the first round is completely unstructured, asking members to express any opinions that they may have on the issue in question (Hill and Fowles, 1975). Variations to the first round are widely described in both the Policy (Turoff, 1970) and Decision (Rauch, 1979) Delphis, consisting mainly of a variation in the amount of structured questioning given. Researchers may limit the first round questionnaire to areas of interest within a subject or, alternatively, the first round may be all but abandoned and replaced with an initial series of consensus statements more typical of a second iteration in a Classical Delphi. As the degree of structuring increases within the first round the generalisability of the returns and subsequent breadth of investigation reduces (Hill and Fowles, 1975).

In this project the initial round of Delphi was constructed to allow participants to derive a list of specific clinical interventions that may be subsequently put out to the whole group to search for consensus. The character of the first round was quite unlike that of a second round Classical Delphi, but retained some structure in order to force all members to consider only those clinical interventions that would be directly relevant.

Round one was released at the beginning of March 2002, and consisted of an e-mailed introductory letter together with a request for specific clinical interventions that members felt could prove helpful in triage after a major incident. Some guidance

was necessary and a series of general examples were provided to help guide members appropriately.

Sixteen replies were received within 4 weeks, after one reminder for several members.

### **8-7-2b: Round Two**

The results of stage one were collated into a series of clinical criteria representing clinical interventions that may occur to children following injury in a major incident. There were 39 such criteria, and these were presented to the group in table form, together with detailed completion instructions as shown at **appendix 5** and **table 8.1**. Participants were asked to consider the triage priority that they believed the child should have been assigned, knowing the intervention that had been necessary for that child.

Three members of the panel had some difficulty with the concept of round two, stating that it would be impossible to know that the child would need such an intervention without undertaking detailed assessment. Clarification was sent to all panel members by email, stating that the idea of this Delphi was to imagine that the child had been fully seen and sorted by appropriate medical care: when the panel member was later reviewing the child's notes they saw that he / she had received this intervention. On the basis of this knowledge, the members were asked to decide what priority they think the child should have been given at the scene if this information had somehow been available at the time of triage.

Number	Intervention required
1	Blood within 30 minutes of arrival at ED
2	Cardiac Arrest Protocol (pulse present on first triage)
3	Chest Drain Insertion
4	Cricothyroidotomy
5	CT abdomen / chest within 1 hour of arrival
6	CT head within 1 hour of arrival
7	Direct pressure to control severe haemorrhage
8	DPL or FAST Ultrasound in ED
9	Escharotomy in ED
10	External Pelvic fixation within 1 hour
11	Fluid resuscitation in excess of 20 ml / kg
12	Intravenous analgesia in ED
13	Intubation and ventilation (unless non-emergent, e.g. for CT)
14	Laryngeal Mask Airway (unless non-emergent)
15	Long Bone splint application Femur
16	Long Bone splint application Lower Leg
17	Nasopharyngeal Airway insertion for airway protection
18	Needle Cricothyrotomy
19	Needle thoracocentesis
20	Opiate analgesia (not intravenous)
21	Oropharyngeal Airway insertion for airway protection
22	Pericardiocentesis
23	Plaster of Paris application (forearm)
24	Plaster of Paris application (long arm)
25	Plaster of Paris application (long leg PoP)
26	Simple dressing application
27	Sling application
28	Sutures
29	Tourniquet to control severe haemorrhage
30	Need a laparotomy within 1 hour
31	Need a laparotomy within 6 hours
32	Need a laparotomy within 1 day
33	Need a thoracotomy in ED
34	Need a thoracotomy within 1 hour
35	Need a thoracotomy within 6 hours
36	Need a thoracotomy within 1 day
37	Need theatre within 1 hour (other operation)
38	Need theatre within 6 hours (other operation)
39	Need theatre within 1 day (other operation)

ED = Emergency Department

**TABLE 8.1: List of criteria developed after round one of Delphi study**

Other members raised the issue that specific triage category would depend upon the amount of medical resources available. The email message discussed above contained details that there were enough medical resources to avoid the need for the expectant category at scene.

Round two was released in May 2002, with follow up emails in the same month. The only null return by 1 July was chased and all results were in by 10 July 2002. Consensus was considered to have been reached if 13 of the 16 panel members agreed on an issue. Fourteen of the round two items achieved consensus.

### **8-7-2c: Round Three**

In round three participants score their initial statements in the light of the results from round two: they are fed back with their own answers and those of the group as a whole. Most of the observed shift in opinion and view is likely to be seen between round two and three (Linstone and Turoff, 1975). This shift occurs primarily as group members become aware of the degree of expertise of other panellists and tend to shift their answers towards the majority opinion. This is most likely to happen in those who believe their level of knowledge inferior to other members of the group.

In subsequent rounds individuals are more likely to keep replying in the same manner. This has the risk of introducing measurement bias, and is in large part due to boredom with the Delphi process (Martino, 1972).

Those statements that had reached consensus at round two were removed from the Delphi at this stage. Twenty eight items were sent back to the group, along with the further information as detailed in **appendix 6**. In keeping with the design of a Decision Delphi (Rauch, 1979) the identity of the participating members of the



Delphi group was included at this time. It was hoped that on seeing the seniority and diversity of the other panel members individuals would be encouraged to put “more effort” into their answers.

Round three was release in mid July, and a chaser email was sent one month later. All answers were received by September 2002. A further 15 items achieved consensus, meaning a total of 29 clinical interventions achieved consensus.

### **8-8: Results**

There were 39 criteria derived in round one. Of these, 29 achieved a consensus level of agreement (13 of the 16 panel members): this is equivalent to 81.25%, and is a moderately high cut off for consensus. These are shown at **table 8.2**. Eight of the criteria were listed as T3: they were considered to reflect interventions that injured children could wait some time to receive in a major incident setting. Three were T2 interventions. The remaining 18 criteria were considered to be T1 – they would be required immediately by injured children in a major incident setting.

Of the remaining 10 items, three achieved agreements of two-thirds or higher (11 members agreed) (T2 - need a laparotomy within six hours, need a thoracotomy within six hours; T3 – need a thoracotomy within one day). All other items had a wide spread of opinions.

Triage Category		
T1	T2	T3
Blood within 30 minutes of arrival at ED	DPL or FAST Ultrasound in ED	PoP application (long leg)
Chest Drain Insertion	Intravenous analgesia in ED	PoP application (forearm)
Cricothyrotomy	Femoral splint application	PoP application (long arm)
Direct pressure to control severe haemorrhage		Simple dressing application
External Pelvic fixation within 1 hour		Sling application
Fluid resuscitation in excess of 20 ml / kg		Sutures
Intubation and ventilation (unless non-emergent)		Need a laparotomy within 1 day
Laryngeal Mask Airway (unless non-emergent)		Need theatre within 1 day (other operation)
Nasopharyngeal Airway insertion for airway protection		
Needle Cricothyrotomy		
Needle thoracocentesis		
Oropharyngeal Airway insertion for airway protection		
Pericardiocentesis		
Tourniquet to control severe haemorrhage		
Need a laparotomy within 1 hour		
Need a thoracotomy in ED		
Need a thoracotomy within 1 hour		
Need theatre within 1 hour (other operation)		

ED = Emergency Department

**TABLE 8.2: Delphi Consensus Criteria**

## 8-9: Discussion

Formal validation of any triage tool would ideally occur in the setting in which that tool is to be used. However, in the case of major incident tools this is not possible. Current major incident triage methodologies such as the Triage Sieve (Advanced Life Support Group, 2002), have been adapted from scores designed to triage individual patients (predominantly adults). Progress on major incident methods is hampered by the lack of a gold standard for what a major incident triage score must do. When determining the success of a triage score it is important to define what factors it is trying to discriminate. To truly determine the success of a major incident score it must be measured against what it is intended to achieve, i.e. the need for clinical intervention, not just injury or physiological derangement (although these will often co-exist).

The use of expert derived criteria as a means for testing triage tools has been established by both Baxt (Baxt and Upenieks, 1990) and Garner (Garner et al, 2001): this method is preferable to the use of the ISS as it allows for correct identification of casualties based upon medical need, rather than on specific injury severities alone. It can be applied in the validation of specific triage tools. The derivation of appropriate criteria to test against can be by committee (although the problems with this have been identified), or by alternative means.

This Delphi study has developed the work of Garner *et al* by determining similar clinical criteria, but through the use of a Delphi process rather than the authors' own expert opinion. The criteria derived are not intended to be used to triage children at the scene of a real major incident, but rather provide a means by which a

triage algorithm can be validated, by testing its ability to identify patients in need of such clinical interventions.

The Delphi design was chosen for this study as the outcome (i.e. the relative need for clinical intervention in major incidents) can only be determined by an expert group with knowledge of major incident management and clinical care. This approach combines opinion in a structured and anonymous manner. However, the decisions made are determined entirely by the group members and these are potentially influenced by past experience or work in the field.

The criteria derived are specific to the situation detailed in the Delphi information (**appendix 5 and 6**), although the general principal may be used in other situations to test other tools. This methodology may be used to derive further specific lists of criteria against which other current and future triage tools may be tested (both for paediatric and adult major incidents). The list of conditions in this Delphi was not intended to be exclusive, but may serve as a benchmark in future studies: the principles are equally applicable to the adult population as well – specific intervention lists could be derived by future researchers in this area.

A decision was made to derive explicit T3 criteria: it is accepted that an alternative approach to this would be to derive criteria for T1 and T2, and regard all other patients as T3.

The criteria from this Delphi can be applied to determine the ability of a triage tool to identify the correct triage category. Some worked examples will demonstrate the utility of the Delphi results for future studies:

- A three month old child is unable to walk developmentally. He is involved in a major incident and is triaged using three different triage tools. Using the

PTT, he is noted to be alert and moving all limbs, and is triaged T3. Using START, he is triaged T1 (he is alert, has a palpable pulse but has a RR of 40). With Careflight, he is triaged T2 as he is alert and has a palpable pulse. He is later found to have a minor laceration to the arm that requires sutures. The Delphi panel felt that this child should be triaged T3. He has been correctly triaged by the PTT, but overtriaged by the other two algorithms.

- A child (nine years old) is unable to walk due to injuries received in a major incident. He is able to obey commands, and has normal HR and RR for his age. He is triaged T2 by the PTT on the basis of this; both Careflight and JumpSTART also triage him T2. He is later found to require a thoracotomy within one hour. The Delphi panel agreed that he should have been triaged priority one at the scene, and therefore the triage tools all under-triaged him.

These examples illustrate how a Delphi study such as this may be used to compare existing or newly developed triage tools.

### **8-10: Summary**

- The use of Delphi methodology is a useful means of deriving outcomes for validation of specific triage tools. The intervention criteria derived in this manner are specific for the situation described in the Delphi (in this case, for the validation of a primary triage tool for children), but the same principal may be applied to guide future researchers.
- The criteria developed in this Delphi are more appropriate outcome measures than the use of ISS or other injury-related scoring systems.

## CHAPTER 9:

### RED CROSS CHILDREN'S HOSPITAL STUDY DATABASE

- 9-1 Introduction
- 9-2 Methods
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  - 9-3-1 Demographics
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## **9-1: Introduction**

When deriving a triage tool (regardless of the use it is intended for), the first stage is typically retrospective analysis of trauma registries with appropriate statistical modelling (such as Receiver Operator Curve construction) to determine the most predictive levels of cut off for the selected variables. The derived tool must then be prospectively tested in order to properly ensure validity (although this is often not done). This process was not followed for any of the commonly used paediatric primary triage tools. The PTT was developed by expert opinion, using a modification of the Triage Sieve (itself a modification of an existing tool – TRTS).

The lack of prior derivation studies cannot be addressed by this thesis: however, prospective validation of the PTT is required to determine whether it is actually usefully doing the job for which it is intended. There are problems with validation of such tools in any setting other than a major incident, as have been presented: however, testing in real major incidents is unlikely ever to occur (see **Chapter 4**).

As the majority of patients from major incidents are affected by trauma (Carley et al, 1998), it is appropriate to undertake this testing on trauma patients (it would, however, be interesting to see comparable results on a medical cohort, or mixed medical – trauma patients).

A prospective validation study was undertaken at the Red Cross War Memorial Children's Hospital in Cape Town. The purpose of this chapter is to describe the database of injured children that was established for the validation process.

## 9-2: Methods

The methods used to recruit children for the validation of the PTT are described in that chapter (**Chapter 11**). All children who were recruited for the study had their data collected by the author on a standardised data collection form, designed and modified after a preliminary trial on 250 children (**appendix 7**). All data were entered into a Microsoft Excel® database.

Basic descriptive analyses were undertaken on the database, detailing (where appropriate) mean, median, range and IQR. All data analyses for this section were done on Microsoft Excel®, using Analyse-It® software.

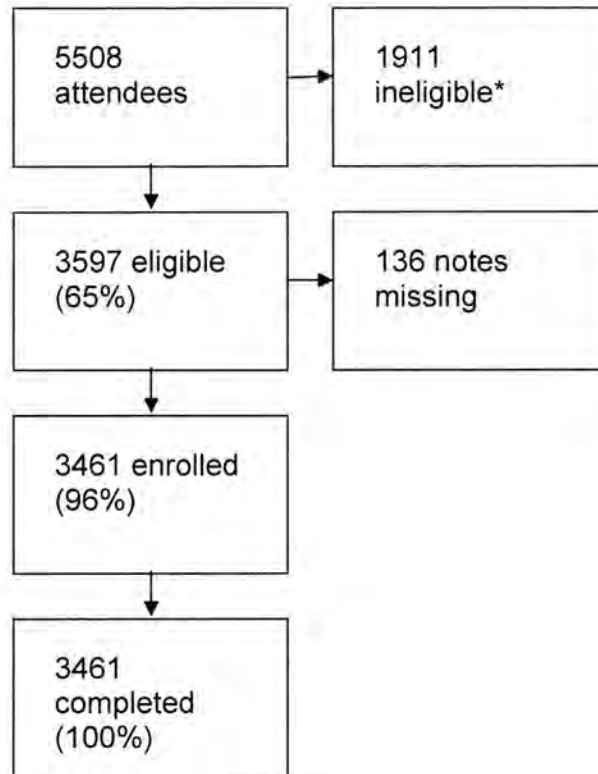
Height and weight were plotted against UK 90 growth reference charts (Freeman et al. 1995), to establish how the study population at RXH compared to the UK growth standards (and to the samples of UK children on whom the physiological reference ranges were derived).

## 9-3: Results

Data were collected at RXH from March to November 2002. A total of 5508 children were seen in the Trauma Unit in that time (mean 612 per month). Of these, 3597 met entry criteria for the study and 3461 had data entered: see **figure 9.1**.

The 1911 ineligible children were either too old (32), or presented more than 12 hours after their injury (1879).





**Figure 9.1: Patient flow at RXH**

### 9-3-1: Demographics

There were 2181 males (63%) in the study population, compared to 64.8% of total attendees in the study period ( $p=0.03$ ). The age and sex breakdown of the children is shown at **Table 9.1**. The ethnic distribution of the study population and all attendees is shown at **table 9.2**.

The mechanism of injury data are presented at **Table 9.3**. The majority (36.4%) were simple falls (under 2 metres) whilst 15.8% were pedestrians involved in motor vehicle accidents. Fifty seven percent of children presented to the unit within one hour of the injury, and over 70% of all children attended within two hours: these data are at **Table 9.4**. The mean time to attendance was 2.5 hours (median one hour, IQR 1-3 hours).

Age (years)	Male	Female	Total (%)
<1	128	100	228 (6.6)
1	276	202	478 (13.8)
2	214	147	361 (10.4)
3	175	117	292 (8.4)
4	207	97	304 (8.8)
5	183	92	275 (7.9)
6	185	94	279 (8.1)
7	147	95	242 (7.0)
8	137	73	210 (6.1)
9	132	68	200 (5.8)
10	123	68	191 (5.5)
11	121	72	193(5.6)
12	153	55	208 (6.0)
	<b>2181</b>	<b>1280</b>	

**A: all children**

Age (months)	Male	Female	Total (%)
0.25	2	0	2 (0.9)
1	10	6	16 (7.0)
2	5	5	10 (4.4)
3	6	8	14 (6.1)
4	7	8	15 (6.6)
5	9	9	18 (7.9)
6	9	8	17 (7.5)
7	22	11	33 (14.5)
8	15	8	23 (10.1)
9	9	9	18 (7.9)
10	19	18	37 (16.2)
11	15	10	25 (11.0)

**B: under 1 year old. n=228**

**Table 9.1: Age and sex distribution of children in RXH database. n=3461**

	Study Population				Total attendees	p value
	Male	Female	n	%	%	
<b>Black</b>	1156	781	1937	56.0	58.9	<0.05
<b>Coloured</b>	695	344	1039	30.0	29.7	0.97
<b>Asian</b>	199	80	279	8.1	7.6	0.3
<b>White</b>	76	45	121	3.5	1.8	<0.001
<b>Other</b>	55	30	85	2.5	1.9	<0.05

**Table 9.2: Ethnic origin of study population and all attendees**

Mechanism	n	%
Blunt Other	529	15.3
Burn	415	12.0
Fall (<2m)	1260	36.4
Fall (>2m)	150	4.3
MVA	133	3.8
MVA (Bicycle)	66	1.9
MVA (Pedestrian)	546	15.8
Knife	24	0.7
Gunshot	19	0.5
Penetrating Injury	3	0.1
Other	316	9.1

MVA = Motor Vehicle Accident

**Table 9.3: Mechanism of injury. n=3461**

Hours from injury	n	%	Cumulative %
1	1983	57.3	57.3
2	493	14.2	71.5
3	229	6.6	78.1
4	205	5.9	84
5	90	2.6	86.6
6	122	3.5	90.1
7	46	1.3	91.4
8	68	2.0	93.4
9	38	1.1	94.5
10	71	2.1	96.6
11	18	0.5	97.1
12	98	2.8	100

**Table 9.4: Time to presentation, RXH database. n=3461**

There were five patients sized below 50cm (the lower size limit of the PTT). Five hundred and twenty-nine were 50-80cm in height, 862 80-100cm, 1660 100-140cm and 405 were over 140cm (the upper size limit of the PTT).

### 9-3-2: Height and Weight

The mean height and median weight data of the study population were plotted by sex against UK 90 growth reference charts and found to lie in all instances between the 25<sup>th</sup> and 50<sup>th</sup> centiles.

### 9-3-3: Outcomes

A total of 1825 (52.7%) children were discharged home from the Trauma Unit; a further 18 (0.52%) died in the Trauma Unit, leaving 46.8% of children to be admitted. One hundred and twelve children were admitted to ICU during the study period (mean 12 per month). The mean length of stay for those admitted was 4.4 days, and for those admitted to ICU the mean stay on the unit was 4.3 days. **Table 9.5** shows the timing of the 33 deaths that occurred in the study period. Fifteen of the deaths occurred after admission from the Trauma Unit: 14 in ICU and one in theatre.

Days post injury	n	%
0*	18	54.5
0**	9	27.3
1	4	12.1
2	2	6.1

\* = died in the Trauma Unit      \*\* = died after admission

**Table 9.5: Deaths in the study period. n=33**

Seven hundred and eighty seven patients (22.7%) underwent surgery as a result of their injury. Eighty percent of these operations occurred on the day of admission, and the majority (341, 43.3%) were orthopaedic procedures (**table 9.6**).

Days post injury	n	%	Cumulative%
0	630	80.1	80.1
1	36	4.6	84.7
2	53	6.7	91.4
3	38	4.8	96.2
4	13	1.7	97.9
5	8	1.0	98.9
6	2	0.3	99.2
7	3	0.4	99.6
8	1	0.1	99.7
10	1	0.1	99.8
12	2	0.3	100

**A: time to first operation. n=787**

Craniotomy	20
MUA	341
Washout	45
Elevate	5
Repair	155
Laparotomy	7
Other	214

MUA = manipulation under anaesthesia  
 Elevate = elevation of depressed skull fracture  
 Repair = wound cleaning and closure

**B: type of operation**

**Table 9.6: Operative interventions.**

There were 188 patients (5.4%) with an ISS of 16+, of which five died. The median ISS was 2 (IQR 1-4). A total of 314 (9.1%) children had a NISS 16+ (five died); the median NISS was also 2 (IQR 1-4). Three hundred and ninety four

(11.4%) had a PTS of eight or lower (33 died); the mean PTS was 10.2 (median 11, IQR 10-11).

The modified Garner criteria occurred 312 times in 200 children (5.8%) (**table 9.7**): requirement for fluid resuscitation was the most common criterion, occurring in nearly half of these children (and two-thirds when only one criterion was present). One hundred and twenty one children had only one criterion present, and no child had all five.

	Frequency of occurrence of criterion*		Presence of single criterion**	
	n	%	n	%
<b>Op</b>	28	9.0	10	8.3
<b>&gt;20ml / kg</b>	140	44.9	75	62.0
<b>CNS</b>	38	12.2	6	5.0
<b>Airway</b>	101	32.4	30	24.8
<b>Tension</b>	5	1.6	0	0.0

- Op = non-orthopaedic operation within 6 hours
- >20ml/kg = requirement for fluid resuscitation over 20ml/kg body weight
- CNS = invasive CNS monitoring or positive head CT
- Airway = a procedure to maintain the airway, or assisted ventilation
- Tension = decompression of a tension pneumothorax

\* n=346

\*\* n=121

**Table 9.7: Frequency of occurrence of Garner criteria**

### 9-3-4: Triage Categories

When analysed by the different primary triage tools, 109 patients were triaged T1 by the PTT, 785 by the Triage Sieve, 188 by TRTS and 185 by Careflight. There were 1020 children triaged by START (aged under one or over eight years): of

these 231 were triaged T1. The remaining 2441 were triaged by JumpSTART methodology, with 55 being T1. The total breakdown of triage category by different triage algorithms is illustrated at **tables 9.8 and 9.9.**

	PTT		JumpSTART		START		Careflight	
	n	%	n *	%	n**	%	n	%
<b>DEAD</b>	9	0.3	0	0.0	0	0.0	0	0.0
<b>T1</b>	109	3.1	55	1.6	231	6.7	129	3.7
<b>T2</b>	383	11.1	688	19.9	129	3.7	988	28.5
<b>T3</b>	2960	85.5	1698	49.1	660	19.1	2344	67.7
<b>UNCODED<sup>#</sup></b>	0	0.0	1020	29.5	2441	70.5	0	0.0

\* n=2441

\*\* n=1020

<sup>#</sup>Uncoded unable to triage by this methodology:  
for START / JumpSTART this is in accordance with user instructions (age under eight years, JumpSTART; over eight years, START)

**Table 9.8: Triage priority coding by different primary triage tools. n=3461**

	Triage Sieve		TRTS		Delphi	
	n	%	n	%	n	%
<b>DEAD</b>	9	0.3	0	0.0	0	0.0
<b>T1</b>	785	22.7	188	5.4	199	5.7
<b>T2</b>	295	8.5	658	19.0	149	4.3
<b>T3</b>	2372	68.5	2615	75.6	1710	49.4
<b>UNCODED<sup>#</sup></b>	0	0.0	0	0.0	1403	40.5

<sup>#</sup>Uncoded unable to triage by this methodology:  
for Delphi, this is due to absence of criteria in 1403 patients

**Table 9.9: Triage priority coding by TRTS, Triage Sieve and Delphi criteria. n=3461**

## **9-4: Discussion**

A 12 hour cut off for entry into a study interested in the response to acute injury may be considered to be excessively long: this may also be the case for major incident studies. However, there are no data concerning the time to presentation for casualties in major incidents in the UK. Furthermore, whilst 12 hours may be excessive in areas with rapid access to assessment of casualties, this may not be the case in other areas where the PTT has the potential to be used. In larger major incidents, remote incidents, and in incidents occurring in less well developed countries (for example in South Africa), the time from injury to assessment will be longer than is typically the case in normal day-to-day European practice. The time limit of 12 hours was chosen as an arbitrary cut off that was felt to represent patients who attended hospital as a result of their primary injury rather than as a result of a secondary deterioration from an initial injury. In this study, over 70% of children were seen within two hours of their injury; only 4% presented after 10 hours. The majority of children were therefore seen in what may be regarded as a realistic time frame in the event of a major incident.

### **9-4-1: Demographics**

In the nine-month study period there were 5508 new attendances seen in RXH. The attendance rate is slightly lower than expected from that reported on an annual basis for the preceding 11 years at the Trauma Unit: an average of 8074 new patients (6055 in nine months pro rata).

Of all eligible patients, 87.5% had their data captured. The commonest reason for not capturing the patient was missing notes (despite all efforts to enter patients'



details on the day of attendance). There are no data regarding the number of those missing patients who were admitted or discharged: as patients who were admitted were followed during their inpatient time, the majority of missing notes were from children who had been discharged (although it is accepted as a weakness of this study that no record was kept of the disposal of these missing patients).

The sex and ethnic mix of the study population had some statistical differences from the total attendees during the study period: there were slightly fewer males (63% vs 64.8%), more blacks (58.9% vs 56%) and more whites and “other” races (6% vs 3.7%). It is very unlikely that this will affect the results of the validation study, and should have no effect on the external validity of these results.

The Child Accident Prevention Foundation of Southern Africa (CAPFSA) keeps a database of all injured children attending the RXH Trauma Unit (although it is unsuitable to use for the validation of the PTT as it does not record physiological data). Between the years of 1991 and 2001 (eleven years) the database captured 71566 of 88822 patients (80.5%). Forty five percent of these injuries were due to falls (36.4% in this study) and 16.6% due to pedestrian motor vehicle accidents (15.8% in this study).

#### **9-4-2: Height and Weight**

Although no statistical assessment has been undertaken, a pragmatic approach to height and weight has been used. The UK 90 growth reference charts illustrate the growth standards for that population. Both the sample from the Chris Hani school and the RXH database sample were plotted against these standards and found to lie comfortably between the 25<sup>th</sup> and 50<sup>th</sup> centiles in all cases, with mean /

median values being identical between the two South African groups in many cases. From a growth perspective, the injured children in this database may be considered the same as the Chris Hani school children. As they share a similar socio-ethnic mix, the assumption may be made that they should have the same range of resting physiological values.

#### **9-4-3: Outcomes**

Eighteen children in the study population died in the Trauma Unit, and one child in theatre. There were 112 children admitted to ICU (3.2%), of whom 14 died. Therefore a total of 130 (3.8%) had a combined endpoint of death or ICU admission. This suggests that the majority of cases were more minor in nature, a fact confirmed by the ISS profile of the study patients. This initially came as a surprise, given the high numbers of severely injured children on the CAPFSA database and the daily workload experienced by the author in the Trauma Unit. However, RXH is a tertiary referral hospital, draining the Western Cape region – the majority of the severely injured patients seen in the Trauma Unit are referred following stabilisation in other hospitals. As a result of this and limitations in the availability of ambulances, most do not arrive within 12 hours of injury. Of the 1911 children not entered into the study, 302 had an ISS of 16+, 396 had NISS 16+, 435 had a PTS of eight or less. Of the 5508 children attending within the study period, therefore, 490 (8.9%) were seriously injured as defined by ISS, 710 (12.9%) defined by NISS and 829(15.1%) as defined by PTS.

The severity of cases in this database is clearly less than in large trauma registries (such as TARNLET in the UK): however, such registries typically exclude

children who are discharged from the Emergency Unit, thereby specifically excluding patients with minor injuries. In a recent report of almost 12000 children in the UK, 19% had an ISS of 16+, compared to 5.4% in this study (12.9% of all attendees) (Dark et al, 2002).

Although specific data on the casualty profile of large numbers of major incidents is often missing, where it has been reported (Carley and Mackway-Jones, 1997) the vast majority of casualties are minor, as reflected by the severity of the population in this study. Validating a triage tool on a population where there are many seriously injured patients may mis-represent the performance of the tool in situations with less serious patients.

#### **9-4-4: Triage Category**

All children were triaged by each of the different triage tools available. Only 1020 (29.5%) were triaged by START, in accordance with the users' instructions for JumpSTART (Romig, 2002). Not unexpectedly, the majority of children were triaged T3 by all tools: this is consistent with the casualty profile from major incidents (where recorded) and the ISS profiles of the study patients.

The Triage Sieve is based upon adult physiological data and one would expect, therefore, that children would be afforded higher triage priority by this tool: this was found to be the case, with 785 (22.7%) triaged T1. The same was noted with START (231 of 1020 children; 22.6%). Although the same rationale may be applied to TRTS, only 188 (5.4%) were triaged T1 by this tool: the explanation to this may lie in the poor discriminative value of SBP and GCS (although no further analysis of this has been undertaken and therefore further comment is not possible).

## **9-5: Summary**

- The characteristics of the children in the database derived for the validation of the PTT have been presented. Most of the children had minor injuries, as would appear to be typical of the casualty profile of major incidents.

## **CHAPTER 10:**

### **ANALYSIS OF THE DELPHI CRITERIA**

- 10-1 Introduction
- 10-2 Methods
- 10-3 Results
- 10-4 Discussion
- 10-5 Summary

## **10-1: Introduction**

Twenty nine criteria were determined by the expert Delphi panel as being appropriate indicators of T1, T2 or T3 triage category in children in major incidents. Eighteen of these are indicators of T1 category; three indicate T2 and eight indicate T3. These criteria were used as part of the validation process for the PTT, although validation also occurred against more typical measurement standards such as ISS (as this is the only current widely accepted method for such validation, despite its flaws).

The decision was taken to actively seek T3 patients, rather than assuming that all those who did not meet T1 or T2 criteria were T3. While different results would be expected for these alternate two ways of analysis, the former was chosen because it is accepted that the Delphi is unlikely to have produced a fully comprehensive list of T1 and T2 criteria. Therefore, assuming that a patient is T3 simply because they did not have any of the derived T1 or T2 criteria may have resulted in undertriage.

The Delphi criteria are not expected to correlate closely with ISS scores (or NISS or PTS), for reasons given previously. However, if they are to be used for the PTT validation it is important to understand of the degree of agreement with these more traditional measures. The purpose of this chapter is to determine the predictive ability of the Delphi criteria at identifying children with serious injuries (as defined by ISS, NISS or PTS).

The degree of agreement between the presence of Delphi criteria and the presence of modified Garner criteria is also assessed in this chapter (this is expected to be low as only three of the five modified Garner criteria occur in the 18 T1 Delphi criteria).

## 10-2: Methods

This analysis was undertaken on the 3461 children in the RXH database. The Delphi criteria were assessed for their ability to identify children with an ISS of 16+ (or NISS 16+ / PTS <9 / the presence of modified Garner criteria). This was calculated by construction of a two-by-two table for each of the measurement standards (as shown in **table 10.1**). Calculation of sensitivity, specificity, NPV, PPV, overtriage and undertriage rates was then undertaken as previously described (**Chapter 3**). All data analyses for this chapter were undertaken on Analyse-It® for Microsoft Excel®.

		ISS		
		16+	<16	
Delphi	T1	A	B	A+B
	Not T1	C	D	C+D
		A+C	B+D	A+B+C+D

**Table 10.1: Two-by-two table**

## 10-3: Results

Of the 3461 children studied, 2058 were triaged by the Delphi criteria: the frequency of occurrence of the criteria is shown in **table 10.2**. Of the 29 Delphi criteria that reached consensus, nine did not occur at all in the database. The 20 criteria that did occur appeared a total of 4041 times in 2058 children. The T1 criteria occurred 254 times in 199 children; T2 criteria occurred 303 times but only 149 were triaged T2 by this means. The T3 criteria appeared 3588 times; a total of 1710 children were triaged T3 by the Delphi.

The T3 criteria clearly occurred many more times than led to triage as T3 – in these cases, either more than one criterion was present in one child, or a T2 or T1 criterion was present leading to a higher triage category.

The commonest reason to be triage T1 by the Delphi, in keeping with the results for the modified Garner criteria, was requirement for fluid resuscitation in excess of 20ml/kg (139 patients). With regard to T2 criteria, the requirement for IV analgesia was the commonest, occurring 178 times. The application of a simple dressing was the commonest occurring T3 criterion, appearing 1073 times.

The characteristics of those patients who had Delphi criteria present (n=2058) and those who had no criteria (n=1403) are presented at **table 10.3**.

The 2058 children who were triaged by the Delphi were analysed to determine the utility of the Delphi criteria at predicting the following outcomes: ISS 16+, NISS 16+, PTS <9 and the presence of the modified Garner criteria. These results are shown at **table 10.4**.



<b>T1 criteria</b>	<b>n</b>	<b>T2 criteria</b>	<b>n</b>	<b>T3 criteria</b>	<b>n</b>
Blood within 30 minutes of arrival at ED	7	DPL or FAST Ultrasound in ED	0	PoP application (long leg)	116
Chest Drain Insertion	55	Intravenous analgesia in ED	175	PoP application (forearm)	134
Cricothyrotomy	0	Femoral splint application	128	PoP application (long arm)	1073
Direct pressure to control severe haemorrhage	3			Simple dressing application	593
External Pelvic fixation within 1 hour	1			Sling application	479
Fluid resuscitation in excess of 20 ml / kg	139			Sutures	671
Intubation and ventilation (unless elective)	99			Need a laparotomy within 1 day	0
Laryngeal Mask Airway (unless elective)	0			Need theatre within 1 day (other operation)	522
Nasopharyngeal Airway insertion for airway protection	0				
Needle Cricothyrotomy	0				
Needle thoracocentesis	5				
Oropharyngeal Airway insertion for airway protection	2				
Pericardiocentesis	0				
Tourniquet to control severe haemorrhage	2				
Need a laparotomy within 1 hour	0				
Need a thoracotomy in ED	1				
Need a thoracotomy within 1 hour	0				
Need theatre within 1 hour (other operation)	0				

**Table 10.2: Frequency of occurrence of Delphi criteria**

	Delphi Criteria	
	Present	Absent
<b>n</b>	2058	1403
<b>mean age (years)</b>	5.2	5.2
<b>Male (%)</b>	74	46
<b>Mean time to present (hours)</b>	2.5	2.5
<b>Died (%)</b>	33 (1.6)	0 (0)
<b>Admit ICU (%)</b>	106 (5.1)	6 (0.4)
<b>Admit ward (%)</b>	1179 (57.3)	325 (23.1)
<b>Mean ISS</b>	4.2	4.1
<b>Mean NISS</b>	5.1	5

**Table 10.3: Characteristics of children with Delphi criteria (n=2058) and those without (n=1403).**

	ISS		NISS		PTS		Garner	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
<b>Sens</b>	8.0	5.0,12.4	8.0	5.5,11.1	40.3	36.2,44.1	12.2	7.6,18.7
<b>Spec</b>	94.4	94.2,94.6	94.5	94.2,94.8	95.5	94.8,96.2	90.5	90.2,90.8
<b>PPV</b>	7.5	4.7,11.7	12.6	8.7,17.6	60.3	54.2,66.1	7.5	4.7,11.8
<b>NPV</b>	94.7	94.5,95.0	91.1	90.9,91.4	90.4	89.8,91.0	94.2	93.9,94.6
<b>OT</b>	92.5	88.3,95.3	87.4	82.4,92.3	39.6	33.9,45.8	92.5	88.2,95.3
<b>UT</b>	5.3	5.0,5.5	8.9	8.6,9.1	9.6	9.0,10.2	5.8	5.3,8.2

Sens            sensitivity  
Spec            specificity  
PPV            positive predictive value  
NPV            negative predictive value  
OT              overtriage  
UT              undertriage

**Table 10.4: Delphi analysis (% , 95% confidence intervals). n=2058**

#### 10-4: Discussion

Consistent with the low proportion of seriously injured children and relative infrequency of modified Garner criteria, only 199 (5.8%) children had T1 Delphi criteria present. This accurately reflects the low proportion of T1 patients reported in major incidents (Carley and Mackway-Jones, 1997).

**Table 10.3** shows the characteristics of those patients with or without Delphi criteria present: while both groups were identical by age and time to presentation to the Trauma Unit, there were significantly more males in the Delphi Criteria Present group: this group also had a higher rate of death, ICU and ward admission. However, there was no difference between the groups in mean ISS or NISS. It is clear that those patients with Delphi criteria present were “sicker” in terms of their outcomes (death, ICU or ward admission); the fact that there was no difference in ISS or NISS reflects the poor utility of these markers in assessment of triage tools.

It is acknowledged that results would have differed if T3 was a “diagnosis of exclusion” of Dead, T1 or T2 status. However, this method of analysis risks undertriage of more serious patients if the Delphi criteria were not fully comprehensive at describing T1 and T2 patients.

The results in **table 10.4** may be interpreted by some to indicate that the criteria derived by the Delphi study are of no use in the validation of major incident triage tools, as their ability to identify seriously injured children is poor: a sensitivity of only 8% at identifying patients with an ISS or NISS of 16+. However, this interpretation would be incorrect, as the Delphi criteria are identifying the need for medical intervention, whilst ISS / NISS merely score injury severity. ISS has

previously been shown to correlate poorly with resource requirement (Baxt and Upenieks, 1990), and these results are consistent with those findings.

The Delphi criteria had very high rates of overtriage against both ISS and NISS (around 90%) – in effect, the presence of T1 Delphi criteria in a patient does not correlate with the presence of a high injury severity. This is as hypothesised, as the need for immediate medical intervention (such as airway manoeuvres) often bears little relation to the severity of the underlying injury (and vice – versa: patients who turn out to have severe injuries often require little intervention immediately). Conversely, the undertriage rates were low (5-10%), indicating that few patients who had severe injuries were triaged T2 or T3 by the Delphi criteria.

The PTS was designed specifically to correlate with high ISS and so the Delphi criteria would be expected to show poor results against this measure. This is indeed the case, although sensitivity is much better (40%) than against ISS / NISS. This may reflect the presence of physiological parameters in the measurement of PTS, as patients who have become physiologically unstable as a result of their injury (and, therefore, score lower and are triaged higher by PTS) are more likely to require immediate intervention. The overtriage rate was accordingly much lower, at 39% (with an undertriage rate under 10%).

The Delphi criteria were not expected to have high sensitivity at identifying the presence of the modified Garner criteria, as the overlap between the two sets of criteria is minimal (even though they are both concerned with identifying patients in need of urgent medical intervention). The recorded sensitivity of 12% reflects this. Both sets of criteria record treatment of a tension pneumothorax, requirement for airway interventions and fluid resuscitation (where agreement will be 100%), but

differ on the other interventions that they record. Garner's criteria are somewhat limited in scope, and it is possible that the Delphi criteria are capturing more "true T1 patients" by having a wider range of T1 criteria (18 rather than five), although no further analysis of this has been made.

This analysis cannot provide any information about the utility of the Delphi criteria at identifying patients who are T2 or T3, as there are no measurement standards against which to judge these.

Rather than assessing the performance of a new validation tool against an inappropriate gold standard such as ISS (or NISS or PTS) (as has been done here), it is more appropriate to test such a tool against real or mock major incident casualty profiles. Such Bayesian analysis is beyond the scope of this thesis, but is being developed by the author and is an interesting avenue for future research. If the Delphi criteria are shown in such an analysis to be accurate predictors of triage category, the use of Delphi derived criteria may become widely accepted as a suitable gold standard for testing major incident triage tools against.

#### **10-5: Summary**

- The Delphi derived criteria were tested to determine their usefulness at identifying seriously injured children: not surprisingly, there was poor correlation between ISS (or NISS) and the presence of such criteria. Correlation with the presence of modified Garner criteria was better, but performance was better against PTS.

- The Delphi criteria need to undergo more rigorous testing (such as that described) before being more widely accepted, but are robust enough to use as a measurement standard for the validation of the PTT.

## CHAPTER 11:

### VALIDATION OF THE PAEDIATRIC TRIAGE TAPE

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## **11-1: Introduction**

The use of the PTT as a primary triage tool in major incidents has been described (**Chapter 3**). How it performs in terms of identification of T1, T2 and T3 patients is not known: this information is not available about any of the primary triage algorithms.

Concerns may be raised about the appropriateness of testing a UK derived tool in South Africa. However, data presented in this thesis failed to find a difference in the resting RR and HR in samples in both countries, despite wide socio-economic differences in the two samples. There is no evidence that different populations of children have differing physiological responses to trauma, and indeed there is no reason to suspect that this may be the case. Accordingly, it is reasonable to assume that there is no difference in the physiological values that are applied when using the PTT in the UK or in South Africa. The results of the validation process in the South African setting may therefore be generalisable back to the UK.

This chapter aims to determine the sensitivity and specificity of the PTT, along with its overtriage and undertriage rates.

## **11-2: Methods**

Ethical approval for the validation of the PTT was gained from the Ethics Board at UCT. Because the project did not involve any identification of the children involved, or any intervention or treatment on the children that affected the care delivered, there was no requirement for the participants to sign informed consent.



### **11-2-1: Design of Data Collection Sheet**

A data collection sheet was designed on Microsoft Word®. It was evaluated in a pilot of 250 children at the start of the study period, and then modifications were made in light of difficulties with the flow of data collection. The final sheet used throughout the study is illustrated at **Appendix 7**.

### **11-2-2: Eligibility Criteria**

Patients were considered eligible for entry into the study if they met the following criteria:

- Aged under 13 years
- Presented within 12 hours of an acute injury.

All other children were excluded from the study.

### **11-2-3: Data Collection**

Data were collected over a nine-month time period, from March – November 2002. The doctors and nurses in the Trauma Unit received an extensive education programme during February 2002, in which they were taught how to collect the necessary data onto the child's Trauma Unit attendance record. The educational session was repeated for new joiners at the unit, and also for all staff after a three-month period had passed.

All staff were shown a standardised method of measuring height in non-walking children with a laminated PTT. For those children who were walking, medical physics fixed a laminated tape measure to a wall in the unit. Staff were

taught to record weight using hospital scales that had been calibrated by the medical physics department. They were recalibrated after three and six months. For those children who were unable to stand on the scales, the ICU bed scales (also regularly calibrated) were used to determine weight on the day of attendance.

The child's HR and blood pressure were measured using Datex S5 Lite® equipment, which was regularly calibrated. All staff were made familiar with this device. Respiratory rate was measured by direct observation for 30 seconds, CRT was recorded from the forehead of all children, and GCS was measured using the standard three components (motor, voice and eye): all techniques were taught until all staff were entirely happy to undertake these measures. Finally, staff learned how to use the PTT, and were made confident and comfortable at triaging with it before the study began. Other information that the duty staff recorded in the patient's notes (in addition to physiological data as shown on the data sheet) included:

- Time of injury
- Time of attendance
- Mechanism of injury
- Triage code as assigned by the PTT
- Disposal of the patient

Additional information that was determined from the data in the patient's records included triage category as assigned by the Triage Sieve, TRTS, START and JumpSTART, and Careflight. The patient's injuries were documented, and an ISS and NISS score was calculated for all (the injuries were determined by medical record review). Each child had an arrival PTS score calculated and documented.

All information was collected by the author, either prospectively as the child came through the unit or at the latest on the day following their attendance. All information was gathered prospectively – for example, if a child was admitted to ICU they were followed on a daily basis until they were discharged or died. The PTT triage category assigned by the nursing staff was checked by the author (using the information available in the medical records, and interviews of the staff involved with the patient) and, if necessary, corrections made to the data sheet.

All data were initially entered onto the data collection form, and then transferred to a Microsoft Excel® spreadsheet. A random 10% of entries were checked after completion of data collection to check the accuracy of data entry.

#### **11-2-4: Data Analysis**

The triage category assigned by the PTT was compared to each of the measurement standards described below. Sensitivity, specificity, positive and negative predictive values, and undertriage and overtriage rates were calculated as previously described (**Chapter 3**). Each value had 95% confidence intervals calculated.

For assessment of the PIT's ability to identify T1 patients, comparison was made against ISS (16+ representing T1 patients), NISS (16+ indicating T1), PTS (under nine indicating T1), the presence of modified Garner criteria, and the presence of T1 Delphi criteria. For assessment of the PTT's ability to identify T2 and T3 patients, comparison was made against the presence of T2 or T3 Delphi criteria only. To determine the PTT's performance against the other commonly used primary triage algorithms, the same calculations were undertaken for CareFlight and START

/ JumpSTART. The PTT was also compared against both the Triage Sieve and TRTS. All data analyses were undertaken on Analyse-It® software, for Microsoft Excel®. These results are presented as **Appendix 8**.

### **11-3: Results**

For all tables presented in this chapter, the following key applies:

- Sens            sensitivity
- Spec           specificity
- PPV            positive predictive value
- NPV            negative predictive value
- OT              overtriage
- UT              undertriage

#### **11-3-1: PTT Identification of T1 Patients**

The PTT's ability to identify T1 patients, as defined by ISS, NISS, PTS, modified Garner criteria and T1 Delphi criteria is presented at table 11.1. Five children were smaller than 50cm, and all were triaged T1 by the PTT. All had ISS and NISS scores below 16, PTS scores of nine or higher and no Garner criteria. None had any of the Delphi criteria present. All were discharged from the Trauma Unit.

**Table 11.2a-e** show the two-by-two constructions undertaken to determine the PTT's performance against ISS, NISS, PTS, Garner criteria and Delphi criteria.

	ISS		NISS		PTS		Garner		Delphi	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
<b>Sens</b>	37.8	32.7, 42.5	26.1	23, 28.8	16.5	13.9, 19.0	41.5	36.8, 45.6	41.7	37.0, 45.8
<b>Spec</b>	98.6	98.3, 98.8	98.9	98.5, 99.1	98.3	97.9, 98.6	98.9	98.6, 99.2	98.9	98.6, 99.2
<b>PPV</b>	60.2	52.1, 67.7	69.5	62.1, 76.8	55.1	46.5, 63.4	70.3	62.5, 77.3	70.3	62.5, 77.2
<b>NPV</b>	96.5	96.2, 96.6	93.1	92.8, 93.3	90.2	89.9, 90.5	96.5	96.2, 96.7	96.5	96.3, 96.8
<b>OT</b>	38.8	32.3, 47.9	30.5	23.2, 38.8	44.9	36.6, 53.5	29.5	22.7, 37.5	29.7	22.8, 37.5
<b>UT</b>	3.5	3.2, 3.8	6.9	6.7, 7.2	9.8	9.5, 10.1	3.5	3.3, 3.8	3.5	3.2, 4.7

**Table 11.1: PTT identification of T1 patients (% , 95% confidence intervals). n=3461**

a.

PTT			
	T1	NOT	
<b>ISS</b>			
<b>16+</b>	71	117	<b>188</b>
<b>&lt;16</b>	47	3226	<b>3273</b>
	<b>118</b>	<b>3343</b>	<b>3461</b>

b.

PTT			
	T1	NOT	
<b>NISS</b>			
<b>16+</b>	82	232	<b>314</b>
<b>&lt;16</b>	36	3111	<b>3147</b>
	<b>118</b>	<b>3343</b>	<b>3461</b>

c.

PTT			
	T1	NOT	
<b>PTS</b>			
<b>&lt;9</b>	65	329	<b>394</b>
<b>9+</b>	53	3014	<b>3067</b>
	<b>118</b>	<b>3343</b>	<b>3461</b>

d.

		PTT		
		T1	NOT	
Garner Criteria	1+	83	117	200
	0	35	3226	3261
		118	3343	3461

e.

		PTT		
		T1	NOT	
Delphi Criteria	1+	83	116	199
	0	35	3227	3262
		118	3343	3461

- Table 11.2:**
- a. PTT performance against ISS, 2 by 2 table.
  - b. PTT performance against NISS, 2 by 2 table.
  - c. PTT performance against PTS, 2 by 2 table.
  - d. PTT performance against Garner, 2 by 2 table.
  - e. PTT performance against ISS, 2 by 2 table.

### 11-3-2: PTT Identification of T2 & T3 Patients

The ability of the PTT to identify T2 and T3 patients (as defined by the presence of T2 or T3 Delphi criteria) is shown at **table 11.3** and **11.4** respectively.

a.

	%	95% CI
<b>Sens</b>	48.2	43.3,53.3
<b>Spec</b>	92.1	18.0,20.4
<b>PPV</b>	34.7	31.0,38.4
<b>NPV</b>	95.4	94.9,95.8
<b>OT</b>	65.3	61.6,69
<b>UT</b>	2.8	2.1,3.5

b.

		PTT		
		T2	T1	
T2 Delphi criteria	1+	133	53	186
	0	250	56	306
		383	109	492

		PTT		
		T2	T3	
T2 Delphi criteria	1+	133	84	217
	0	250	2876	3126
		383	2960	3343

c.

**Table 11.3:** a. PTT ability to identify T2 patients (% , 95% confidence intervals). n=149  
b. Two by two construct for Overtriage  
c. Two by two construct for Undertriage

	%	95% CI
<b>Sens</b>	89.7	88.6,90.8
<b>Spec</b>	19.2	18.0,20.4
<b>PPV</b>	55.7	55.1,56.4
<b>NPV</b>	62.3	58.3,66.1
<b>UT</b>	44.3	43.6,44.9
<b>OT</b>	37.7	33.9,41.7

a.

		PTT		
		T3	NOT	
T3 Delphi criteria	T3	1650	189	1839
	NOT	1310	312	1622
		2960	501	3461

b.

**Table 11.4:** a. PTT ability to identify T3 patients (% , 95% confidence intervals). n=1710  
b. Two by two table for T3 calculations

## 11-4: Discussion

### 11-4-1: The Validation Process

To properly determine the usefulness of a major incident triage algorithm, it is necessary to test its ability to identify not only T1, but also T2 and T3 patients. A

tool that identifies all T1 patients correctly is clearly of great benefit; however, if it misses all T2 patients and triages them as T3 then it will miss patients in urgent need of medical attention. Whilst identification of T1 patients is clearly the most important role that the tool undertakes, its ability to identify T2 and T3 patients is also important to understand, and be aware of, when using such a tool.

Current measurement standards that may be used to identify T1 patients (ISS, NISS, PTS and Garner criteria) have been identified as being of limited usefulness in a major incident setting (see **Chapter 3**). Furthermore, they have no role in the assessment of T2 and T3 patient triage. Accordingly, the only validation process that one can currently undertake for major incident primary triage tools is to validate the ability to identify T1 patients (all other patients are identified as being “not T1”, with no further sub-division possible), and this can only occur in settings other than major incidents (where the performance may be expected to differ significantly).

The answer to this problem may lie in the further development of the Delphi methodology (and is currently being developed by the author), which will help to solve the issue of T2 and T3 performance. Validation in a major incident setting is a problem that is unlikely to ever be resolved: Bayesian analysis of future databases may hold the key to this but for now the current measurement standards are the only accepted means of testing triage algorithms (despite their limitations).

There are no recommended values for sensitivity and specificity of major incident triage algorithms; however, both should be as high as possible in this context to avoid mis-use of resources. Recommended levels of overtriage and undertriage have been produced by the American College of Surgeons (American



College of Surgeons, 1998): they state that a 5-10% undertriage rate is unavoidable, and is associated with an overtriage rate of up to 30-50%.

#### **11-4-2: PTT Identification of T1 Patients**

The PTT performs poorly at identifying children with serious injuries (as defined by ISS, NISS or PTS) - it has a low sensitivity. As major incident triage tools are intended to identify only the urgency of medical intervention required, not the severity of injury, this is neither unexpected nor particularly problematic. The sensitivity at predicting the presence of modified Garner criteria and Delphi criteria is also poor, at around 40%: over half of those children needing urgent medical interventions are not identified by the PTT. Specificity is excellent against all measurement standards, and is likely to reflect the fact that the overwhelming majority of the children are not T1. Undertriage and overtriage rates are well within the accepted limits described by the American College of Surgeons (American College of Surgeons, 1998).

There were only five children who measured below 50cm – all were triaged as T1 in accordance with the instructions on the PTT but there are insufficient data in this study to make reliable conclusions about this as a triage tool.

The low sensitivity of the PTT is clearly a problem, and indicates that modification of the PTT is necessary, in order to improve its sensitivity, whilst minimising overtriage and undertriage. This may be in part due to its reliance on height related physiological values: as this thesis has shown, there appears to be no clear relationship between height and these measures. However, neither Careflight

nor START / JumpSTART rely on height related values and both perform as poorly (or worse).

### **11-4-3: PTT Identification of T2 and T3 Patients**

There are no accepted standards against which to measure a triage tool's ability to identify T2 or T3 patients. This thesis has proposed the use of Delphi derived criteria to undertake such a task, and for this section such analysis has been undertaken against the T2 and T3 Delphi criteria. However, as there are no other measurement standards against which to compare, it is difficult to know how accurate the results are.

For T2 patients, use of the Delphi criteria as the measurement standard showed the PTT to have a sensitivity of just under 50%, meaning that half of such patients are missed by the tool. The specificity is correspondingly high (as the majority of patients are T3). The ACSCOT recommendations on overtriage and undertriage rates apply to tools trying to identify seriously injured (T1) patients and cannot be directly applied to T2 or T3. However, 65% is excessively high as an overtriage rate (although undertriage is a low 2%).

As sensitivity and specificity are prevalence related, the high sensitivity of the PTT at identifying T3 patients is expected, with a correspondingly low specificity. The overtriage and undertriage rates are unacceptably high (calculations for undertriage and overtriage are reversed when compared to T1 / T2): mis-prioritising children who should be T3 as T2 or T1 will result in excessive patients being directed to the scene medical resources when they could actually wait to be seen. However, incorrectly identifying a minor (T3) patient as T2 is less likely to

adversely affect the medical response at scene than a situation where too many children are triaged as T1, as T2 patients are typically dealt with only after the T1 patients.

Similarly, a large number of children who need intervention are not being detected by the tool. This is likely to happen when triage tools use ability to walk as the only marker for prioritising as T3 – a child with a developing tension pneumothorax is likely to be able to remove himself from the scene of an incident for his own safety and, if seen at this point, will be triaged T3. This underlines the requirement for triage to be repeated regularly.

#### **11-4-4: Design of the Paediatric Triage Tape**

The best solution to the poor performance of these paediatric primary triage tools would be design of a new tool from a large retrospective database to optimise its performance, followed by prospective validation and redesign as necessary. This way, sensitivity, specificity and under- and overtriage could be optimised.

This tool could be based upon any of the existing tools, but local sensitivities would need to be considered before attempting to undertake such a project. The database derived for this prospective study is not large or powerful enough to undertake such design.

Alternatively, improvements can be made to the existing tools. For the PTT, as a first step towards re-designing the tool, it is appropriate to consider both the height / weight cut offs that it uses, and the physiological values for each height group. If there are more appropriate values for each of these parameters then the tool

could be redesigned using these values. However, this thesis found no relationship between height and heart rate or respiratory rate.

The design of a new tool is beyond the scope of this thesis, but some of the issues with regard to the performance of the PTT are set out below.

#### **11-4-4a: Height and Weight**

Children who have developed to the point of having adult physiological values risk being overtriaged if triaged by the PTT, whilst those with paediatric physiology may be undertriaged if the Triage Sieve is used on them. The PTT should be designed to keep both to a minimum. It currently has an upper size limit (above which the Triage Sieve should be used) of 140cm, on the basis that this is the size at which children's physiology begins to alter to adult values (stated as being 10 years (Hodgetts et al, 1998)). The equivalent weight value for this height is given as 32kg. The PTT has a lower size limit of 50cm, below which children would be triaged T1.

With regard to the lower size limit, this seems a sensible approach. Typical birth length at term is over 50cm (Freeman et al, 1995); hence, children less than 50cm in length may be reasonably expected to be neonates. Whilst it is unlikely that a given major incident will involve any such children, it remains a possibility. Experience of many pre-hospital staff with such young children is very limited and it is a sensible, pragmatic approach to triage such children T1 for early, more detailed examination. Although the RXH database showed that the five children who were under 50cm had minor injuries, such overtriage is unlikely to adversely affect the overall medical response to an incident as the likelihood of there being more than one such child in a given incident is minimal.

The upper limit of the PTT is set at 140cm (32kg). The UK 90 boys' growth charts (Freeman et al, 1995) show that the 50<sup>th</sup> centile crosses 140cm at age 10.5 years, and crosses 32kg at age 10 years: girls achieve these sizes several months earlier. Using 140cm or 32kg as a cut off, around 25% of eight year olds would be triaged with the Triage Sieve: it is highly unlikely that eight year olds at this size will have adult physiology. Indeed, in the UK reference ranges presented in **figure 6.6** and **6.7**, the upper and lower centiles cross adult physiological values (12-20 breaths per minute for RR, 60-100 beats per minute for HR) at age 13 (HR) or 14 (RR).

If the 13<sup>th</sup> birthday is taken as the cut off on the UK 90 growth charts (although this decision would still be arbitrary – there are no firm data on when adult physiological values begin to apply, although many experts consider this to be from age 13 onwards (Advanced Life Support Group, 2005)), this corresponds to a 50<sup>th</sup> centile height of 155cm (both sexes), and a weight of 43kg (boys) or 45kg (girls). In this study population, 47 (1.4%) were taller than 155cm and 87 (2.5%) weighed over 45kg. This validation study only considered children up to their 13<sup>th</sup> birthday: based on this and the UK 90 growth charts, an upper limit for the PTT of 155cm (or 45kg) would be more appropriate (a weight of 45kg may even be an underestimate, given the recent expansion in waistlines in UK schoolchildren (Rudolf et al, 2004)). At this level, 50% of children at their 13<sup>th</sup> birthday would be triaged with the Triage Sieve, and 50% with the PTT. By age 14, only 25% would be triaged with the PTT, a figure falling off rapidly to 9% by the 15<sup>th</sup> birthday, minimising overtriage. Conversely, only 1 % (>155cm) to 7% (>45kg) of 10 year olds would be triaged by the Triage Sieve, minimising undertriage in this group.

#### 11-4-4b: Physiological Values

The PTT uses RR and HR to help to assign triage category in a height related fashion: the ranges used are shown in **figure 3.5**. The authors had very little evidence on which to base these ranges (Hodgetts et al, 1998), but it is likely that one of the main determinants of the accuracy of the PTT is the physiological values used in its design.

Considering the height blocks used on the PTT, and referring to the UK growth reference charts (Freeman et al, 1995), 50-80cm represents children aged up to approximately 18 months (50th centile = 80cm (girls) / 82cm (boys)); 80-100cm represents children up to approximately four years old (50th centile = 102cm (girls) / 103cm (boys)), and 100-140cm represents children up to approximately 10 years of age. Deriving “normal” ranges for children in these height / age groups requires extrapolation from the centile charts and tables presented in **chapter 7** (including where appropriate, results from Rusconi *et al* (Rusconi et al, 1994)). These are:

- 50-80cm (birth to 18 months) – RR 20-60, HR 110-150
- 80-100cm (18 months to four years) – RR 20-55, HR 75-150
- 100-140cm (four to 10 years) – RR 15-25, HR 60-115

These values derived from the reference ranges presented in this thesis are at odds with the values printed on the PTT (**figure 4.5**) and suggest superficially that the tape may therefore be expected to be inaccurate: if the normal ranges are not correctly understood then the abnormal values used as cut offs cannot be expected to be accurate.

However, it is important to remember that there are no data on which to base the HR values under four years of age, and so those quoted by the APLS course have been used (Advanced Life Support Group, 2005). Furthermore, many assumptions have been used to translate height to age (through growth reference charts), and determine ranges for these ages from incomplete data. It is also important to acknowledge that, no matter how appropriate the ranges printed on the PTT appear to be (based upon values of RR and HR in healthy resting children), the triage tool still needs to be validated (and, if need be, altered).

#### **11-4-5: PTT Compared to Other Triage Tools**

The results referred to in this section are presented as **Appendix 8**. Comparison of the PTT to Careflight and START / JumpSTART was undertaken in the same manner as described above (2241 children were triaged using JumpSTART, and the remaining 1020 using START). Using ISS as the measurement standard for identification of T1 patients, none of these tools had sensitivities that approached acceptable levels (the highest being 48% for Careflight) and, although specificities were good, this represents a serious problem with all of the tools. The sensitivity is much lower than that found by Garner *et al* (Garner et al, 2001), who demonstrated a sensitivity of 82-85% for Careflight, START and the Triage Sieve (for adult patients).

The performance of each tool varied depending upon the measurement standard applied against it: START had a sensitivity of 87% at identifying T1 patients as defined by PTS, but only 22% if the definition is by NISS. However, these measures are not against standards that are appropriate for major incidents – the

performance against modified Garner or Delphi criteria is likely to more accurately reflect performance in such a setting. In this regard, performance was still unacceptably poor, with sensitivities peaking at 64% (meaning that one in three T1 children will be missed by the tool).

The overtriage and undertriage rates for the PTT and Careflight were within the recommendations of the American College of Surgeons, but START and JumpSTART performed very badly in this regard, with overtriage rates up to 98%. Performance was similarly poor at identifying T2 or T3 patients, with low sensitivities for all tools.

Using the most widely accepted measurement standard (ISS), all tools performed sub-optimally. Considering the use of Delphi derived criteria as a measurement standard, none of these tools can be considered acceptable for major incident primary triage, although there is not one tool that is obviously better than the others.

The Triage Sieve demonstrated better sensitivity (with high specificity) than the PTT against all of the measurement standards, although the best sensitivity was still an unacceptably low 72%. However, overtriage rates were much higher – as would be expected for a tool using adult ranges of physiological values. As a result of this, the Triage Sieve would correctly identify more children as needing immediate intervention (T1), whilst at the same time directing many more less urgent children for immediate assessment, creating the risk of flooding the limited medical resources. Performance of the Triage Sieve at identifying T2 patients was slightly worse than the PTT, and that for T3 patients closely matched to the PTT.



Although not a primary triage algorithm, the TRTS demonstrated similar sensitivities and specificities to the PTT; however, the overtriage rate was unacceptably high (perhaps reflecting the use of adult physiological values in its calculation). Furthermore, TRTS is too unwieldy to be of any use for major incident primary triage. As a secondary triage tool, the TRTS is used in conjunction with anatomical information and hence the results of this study cannot be extrapolated to reflect the performance of the Triage Sort.

The recommendation of this thesis must be to redesign these tools in order to improve their performance. In the meantime, the use of START and JumpSTART cannot be considered a safe practice. Personnel using Careflight or PTT to triage should be aware of the limitations of the tools. New, redesigned and validated tools should be introduced at the earliest opportunity. The most sensible alternative to the complete redesign of several separate triage tools would, of course, be to properly design a single tool that can be used by all parties: however, regional and international politics and personalities make this unlikely to ever happen. Neither the Triage Sieve nor the TRTS are useful tools for the primary triage of children in major incidents.

#### **11-5: Summary**

- The PTT performs poorly against both traditional and novel measurement standards, as do Careflight and START / JumpSTART. Using ISS as the gold standard for measurement, Careflight performs best (although only slightly better than the PTT). The continued use of START / JumpSTART cannot be considered safe on the basis of these results.

- If the Delphi criteria are used as the measurement standard, performance of all primary triage tools is poor.
- None of the currently available primary triage tools – paediatric or adult – can be considered suitable for ongoing use. Either the existing tools must be redesigned and then prospectively validated, or (preferably) a new, validated tool must be developed.
- In the meantime, users should be aware of the limitations of the triage algorithm that they are working with.

**CHAPTER 12:**  
**CONCLUSION**

This thesis had three key objectives to fulfil the aim of validating the Paediatric Triage Tape. The first objective was to establish reference ranges of heart rate and respiratory rate in children in the United Kingdom and South Africa. There was no evidence to support currently taught reference ranges of these values in the UK, and no data at all in South Africa. Reference ranges were therefore derived in the UK, and compared to a sample in South Africa. There was no clinically significant difference in the two countries.

The second objective of this thesis was to derive a more appropriate outcome measure against which to test the PTT (and other major incident triage tools). This was undertaken through a Delphi study, and produced a series of interventions that achieved consensus amongst the expert panel as being indicative of appropriate triage categories.

As there were no differences in the physiological ranges between the two countries, validation of the PTT proceeded in South Africa with no data adjustments required. A prospective database was developed and formed the basis of the validation of the PTT. However, for appropriate comparison, validation was also undertaken against more traditional outcome measures, such as ISS. The performance of the PTT was unacceptably poor.

## **CHAPTER 13:**

### **RECOMMENDATIONS**

- 13-1 Heart and Respiratory Rate, United Kingdom Children
- 13-2 Heart and Respiratory Rate, South African Children
- 13-3 The Delphi Criteria
- 13-4 Validation of the Paediatric Triage Tape

### **13-1: Heart and Respiratory Rate, United Kingdom Children**

The currently accepted ranges of HR and RR as produced in paediatric texts are unsupported by evidence. Reference ranges of HR and RR for four to 16 year olds in the UK have been produced by this thesis, and are at odds with those ranges quoted in texts.

#### **Recommendation 1:**

The ranges of heart rate from four to 16 years produced for this thesis be accepted as reference ranges for the UK.

#### **Recommendation 2:**

The ranges of respiratory rate from four to 16 years produced for this thesis be combined with those ranges produced by Rusconi *et al* (Rusconi et al, 1994) and be accepted as reference ranges for the UK.

#### **Recommendation 3:**

Similar reference ranges need to be derived for heart rate for children aged under four years.

#### **Recommendation 4:**

The ranges of paediatric physiological values taught on Life Support courses be modified in light of the findings of this study.

### **13-2: Heart and Respiratory Rate, South African Children**

A sample of five to 16 year old children from socio-economically deprived backgrounds in South Africa had their RR and HR measured: their medians and

interquartile ranges were found to lie well within the reference ranges derived for the UK.

**Recommendation 5:**

The ranges of heart rate and respiratory rate for five to 16 year olds derived for this thesis be accepted as reference ranges for children in South Africa.

**13-3: The Delphi Criteria**

The numerous problems with using currently accepted standards for validating triage tools have been identified. The use of ISS for validation of a major incident primary triage tool is far from ideal, and better measures are needed. The criteria developed by Garner *et al* are more helpful, but are only useful for establishing a tool's ability to identify T1 patients. The criteria developed by the Delphi methodology in this thesis provide a gold standard against which to validate the PTT and, while the criteria derived may not be directly applicable to other triage tools, the methodology is sound and may be repeated for other triage settings.

**Recommendation 6:**

Criteria derived by Delphi methodology should be used as the basis for validation of major incident triage tools.

**13-4: Validation of the Paediatric Triage Tape**

When considering traditional gold standards (such as the ISS, NISS or PTS), the PTT performs poorly: its sensitivity is too low to identify all seriously injured

children. However, it has good specificity, overtriage and undertriage rates. When compared to Garner's criteria and the derived Delphi criteria, the PTT performs better but still suffers from low sensitivity. The poor performance is unlikely to be related to the measurement of height related physiological values, despite this thesis demonstrating no clear relationship between these variables.

Comparisons of the PTT with START / JumpSTART and CareFlight methodology reveals that each of these triage tools exhibits the same weaknesses (in sensitivity predominantly). START and JumpSTART perform too poorly against ISS to recommend their continued usage.

As the use of Careflight methodology requires only one tool for both adults and children, it would be most practical to recommend its use in areas where no tool is currently taught (pending revision / redesign of other tools). If a new triage tool is to be introduced (as is recommended), there will be a reduction in the effectiveness of triage while the tool is learned (Martin, 1993; Emerman, 1995): this must be offset against any gains in performance of the new tool. With this in mind, therefore, in areas where the PTT is currently used it should continue to be used pending design and validation of a new tool. However, for all primary triage algorithms, users must be aware of the limitations of the tool in use. START and JumpSTART cannot be considered safe for use from the results of this study.

**Recommendation 7:**

A new paediatric primary triage tool is needed, derived from regression analysis of a large database of injured children.



**Recommendation 8:**

Such a tool, once designed, needs to be prospectively validated (against both traditional measurement standards such as ISS, and resource-requirement based standards, such as the Delphi criteria derived here).

**Recommendation 9:**

Pending the introduction of a new tool, in areas where the PTT is used it should continue to be used. In areas where Careflight is used, it should be continued to be used.

**Recommendation 10:**

Pending the introduction of a new tool, in areas without a paediatric primary triage tool, Careflight should be introduced.

**Recommendation 11:**

Pending the introduction of a new tool, in areas currently using START / JumpSTART methodology, Careflight should be introduced in place of the current methodology.

**Recommendation 12:**

Pending the introduction of a new tool, users of existing paediatric primary triage tools must be aware of the limitations of the tool that they are using.

## APPENDICES

## Appendix 1

### INFORMATION SHEET

#### **Determination of normal resting vital signs in children**

I would like your son / daughter to take part in research. Here is some information to help you decide whether or not to allow them to take part. Please take time to read it carefully, and ask any questions of myself if you wish. You may take this to your family doctor and ask their advice if you would like to do so.

Your child will not receive any direct benefit from this study. However, the information that I obtain will help medical staff to more accurately identify seriously ill and injured children, and in this way the study will be of benefit for sick children in the future.

#### **Details**

I will attend your child's school, and your child will be out of lessons for no more than 15 minutes. He / she will spend at least 5 minutes sitting quietly, so that the measurements I take will be done at rest. I will spend approximately 5 minutes with him/ her and do the following:

- **Measure height and weight**
- **Place a light monitor probe onto his / her finger to measure heart rate and level of oxygen in his / her blood**
- **Count his / her breathing rate**
- **Press lightly on his / her forehead for 5 seconds, and record the time it takes for normal colour to return (normally 2 seconds or less)**

This is entirely painless and should not distress your child in any way. The nurse or a teacher will be in attendance.

The information that I will gain from assessing several hundred children across Plymouth will help doctors to be able to identify what should be normal for a child of a given height or weight. We already have some information on this, but from only a very small number of children. This larger study will allow us to be able to recognise those children who are in need of rapid medical attention more easily.

Name	Dr Lee A Wallis
Address	Accident and Emergency department Derriford Hospital PLYMOUTH PL6 8DH
Tel	01752 792511

## Appendix 2

### CONSENT FORM

Title of Project

**Determination of normal resting vital signs in children**

Name of researcher

**Dr Lee A Wallis**

Please read, sign and return to the teacher.

I have read and understand the information sheet.

I understand that my child's participation is entirely voluntary, and that I am free to withdraw him / her without reason and without his / her medical care or legal rights being affected.

I understand that I am free to ask questions of the researcher, whose contact details are on the information sheet, at any time.

**I agree / I refuse** (delete as appropriate) to allow my son / daughter to take part in this project.

\_\_\_\_\_  
Name

\_\_\_\_\_  
Date

\_\_\_\_\_  
Name of child

## Appendix 3

### GP INFORMATION SHEET

Title of Project

**Determination of normal resting vital signs in children**

Dear Doctor

I have today examined \_\_\_\_\_ as part of a study to determine the normal resting vital signs of children in all age groups as related to height and weight.

As part of this non-invasive study, I detected a borderline result.

I have asked the parents to bring him / her to see you in due course, for any further investigation as necessary.

Thank you for your assistance

#### **Researcher Contact Details**

Name	Dr Lee A Wallis
Address	Accident and Emergency department Derriford Hospital PLYMOUTH PL6 8DH
Tel	01752 792511

## Appendix 4

### PARENT INFORMATION SHEET

Title of Project

**Determination of normal resting vital signs in children**

Dear

I have today examined \_\_\_\_\_ as part of a study to determine the normal resting vital signs of children. This is the study that you consented to recently.

As part of this examination, I found a borderline result. I would ask you to take him / her to the family doctor in due course to see if it needs to be looked into further.

I have written to your doctor and explained the same thing.

Thank you

#### **Researcher Contact Details**

Name	Dr Lee A Wallis
Address	Accident and Emergency department Derriford Hospital PLYMOUTH PL6 8DH
Tel	01752 792511

## **Appendix 5**

### **Background:**

In a major incident with multiple casualties, the medical response is heavily influenced by the rapid and accurate identification of those patients in need of immediate attention. At the same time, those whose needs can wait must also be identified to avoid overburdening the limited medical resources.

There are many triage instruments available to assist in this process, most of which have not been formally validated. In the context of paediatric casualties, the Paediatric Triage Tape is one such triage tool. The tape relies upon physiological parameters related to height (or weight) to determine the child's triage category. This tape is currently undergoing prospective validation in South Africa.

Part of the problem with validating triage instruments lies in determining which outcomes are considered to represent serious injury. The most commonly used is the Injury Severity Score, but this has many limitations. Some papers have used a short list of outcomes, such as death or the need for surgery within six hours, as indicators of serious injury. All methods have flaws.

I propose a different way to determine the outcomes that will be used to validate this tape: the use of an expert panel in South Africa and the UK. This Delphi study consists of 16 experts, including yourself, and I thank you for taking part.

### **Method:**

With hindsight, knowing the interventions performed on an individual child, it is possible to state what the preferred triage category would have been in order to treat

the child within the optimum time from injury. This is, of course, in the context of multiple casualties: not every patient can be treated immediately.

When triaging patients for treatment, consideration must also be given to the amount of equipment available to you, the number of trained staff at hand, and the environment. For this exercise, please consider that there was access to just enough of everything needed to avoid the introduction of an expectant category into the triage scheme.

Please assume that triage is at the scene of the incident. Furthermore, no treatment has been undertaken before these children are triaged.

On the following pages you will find paediatric patients from a major incident. Please consider each patient in turn, and then, using this hindsight, indicate whether you believe that patient should receive *immediate*, *urgent* or *delayed* treatment, or whether they should be triaged as *dead*. Mark your choice in the columns next to each patient as follows:

- For *immediate* treatment, tick T1
- For *urgent* treatment, needing intervention within 2-4 hours, tick T2
- For *delayed* treatment, needing interventions that can wait over 4 hours, tick T3
- For *dead*, tick DEAD.

Please add any comments that you wish to by any of the patients.

Now read through the scenario, and then turn to the list on pages 4-7.

**Scenario:**



A major incident has occurred involving children. You must triage the injured children. You need to decide whether each child needs *immediate*, *urgent* or *delayed* treatment, or whether, in a major incident setting, they are *dead*.

Using the hindsight of the clinical information provided, look at the following children that are injured and triage them for treatment priority.

## Appendix 6

“Please consider the following examples:

1. A child has been part of a major incident. After he has been discharged from hospital you review his case folder, as you wish to determine whether he was dealt with appropriately. You see that he suffered a tension pneumothorax as a result of the incident. You decide from this information that he should have been triaged as **Priority 1** at the incident scene.
2. You review a second folder, for the same purpose. You see that the child only required a sling for an injury suffered. You decide from this information that the child should have been triaged as **Priority 3** at the incident scene.
3. You review a final folder, and see that the child was admitted to intensive care from the emergency department. You decide from this information that the child should have been triaged as **Priority 1** at the incident scene.

I have deliberately not provided more clinical information on patients as this would then create an infinite list of injuries related to very specific presentations. I have tried to keep each child generalised, and have taken your comments into account from the previous round.

When triaging patients for intervention, consideration must be given to the amount of equipment available to you, the number of trained staff at hand, and the environment. For this exercise, **please consider that there was access to just enough of everything needed to avoid the introduction of an expectant category into the triage scheme.**

Some of the feedback from Round 2 suggested that Triage would differ depending on whether it was undertaken at the scene, at the evacuation point, or at the hospital.

Please **assume that triage is at the scene**. Furthermore, **no treatment has been undertaken before these children are triaged**.

Against each child are the summed responses from Round 2 (n=16) for that patient. Your response in Round 2 is highlighted in **bold**. In the "COMMENTS" column are your written comments from Round 2, if any.

Please consider each patient in turn, and then indicate whether you believe that patient should have received immediate, urgent or delayed treatment, or whether they should have been triaged as dead.

Mark your choice in the column headed "ROUND 3 TRIAGE CATEGORY", next to each patient, as follows:

- For **immediate** treatment, write T1
- For **urgent** treatment, needing intervention within 2-4 hours, write T2
- For **delayed** treatment, needing interventions that can wait over 4 hours, write T3
- For **dead**, write D.

Please add any comments that you wish to by any of the patients, in the column headed "ROUND 3 COMMENTS".

A list of members of the Delphi panel is attached.

## Appendix 7

STUDY NUMBER	
--------------	--

Date of injury	
----------------	--

Patient details OR label
--------------------------

Age Y/M		
------------	--	--

Mechanism / comment											
PK	PG	PO	MVA	MVA B	MVA P	BU	FU6	FO6	BO	OO	

Initial Physiology					Time from injury			
HR		RR		Radial pulse	Y	N	CRT	
SBP		GCS		GCS M				

Initial outcome (ED)						
Death in ER		Admit theatre		Admit ICU		Admit ward
Home						

Final Outcomes						
Death		Date		Cause		
Autopsy findings						
Surgery		Date		Operation		
Findings						
Transfer		Date		Discharge		Date
ICU Los		Total LoS				

Measurements					
Days post injury		Weight		Height	

PTT triage cat		Reason codes	3	0	2A 2B	1A 1B 1C 1D 1E 1F
Sieve triage		Reason codes	3	0	2A 2B	1A 1B 1C 1D 1E 1F
PTT = Sieve?		PTT = PTS?				

TRTS	
Total	

TRTS triage		Agree PTT?		Agree Sieve?		Agree PTS?	
START / JS triage		Agree PTT?		Agree TRTS?		Agree PTS?	
Careflight triage		Agree PTT?		Agree TRTS?		Agree PTS?	

Final triage	Triage cat
Intervention	I1 I2 I3 I4 I5 I6 I7 I8 I9 I10 I11 I12 I13 I14 15 I16 I17 I18 I19 I20 I21 I22 I23 I24 I25 I26 I27 I28 I29
Diagnosis	D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 1D13 D14 D15 D16 D17 D18 D19 D20 D21 D22 D23 D24 D25 D26 D27 D28 D29 D30 D31 D32 D33 D34 D35 D36 D37
Outcome	O1 O2 O3 O4 O5 O6 O7 O8 O9 O10 O11 O12 O13 O14 O15 O16 O17 O18 O19 O20

Paediatric Trauma Score	
Total	+/-

STUDY NUMBER

INJURIES		AIS SCORE
Head & neck		
Face		
Chest		
Abdomen & Pelvic contents		
Extremities & Pelvic girdle		
External		

## **Appendix 8**

### **PTT Compared to Other Primary Triage Tools**

The PTT was compared to JumpSTART / START and CareFlight. The results of the analysis of T1 patients are presented at **table A8.1** for these tools. With regard to T2 patients, results are shown at **table A8.2**. For T3 analysis, these results are at **table A8.3**.

**Table A8.1: T1 results of other primary triage tools (% , 95% confidence intervals). n=3461 (next page)**

	ISS		NISS		PTS		Garner		Delphi		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	
<b>START</b> *	<b>Sens</b>	31.3	21.5, 42.8	22.3	15.6, 30.7	87.6	82.1, 91.7	39.2	29.3, 50	64.9	52.5, 75.7
	<b>Spec</b>	77.9	77.3, 78.7	77.3	76.6, 78.3	88.8	87, 89.5	78.7	77.9, 79.5	79.9	79.1, 80.5
	<b>PPV</b>	8.7	6, 11.9	10.0	7, 13.7	58.0	54.4, 60.7	12.6	9.4, 16	16.0	13.0, 18.7
	<b>NPV</b>	94.4	93.6, 95.4	90.0	89, 90.9	97.6	96.5, 98.4	94.3	9.3, 9.5	97.5	96.6, 98.2
	<b>TO</b>	91.3	88.1, 94	90.0	86.3, 93	42.0	39.3, 45.6	87.5	84, 90.6	84.0	81.3, 87
	<b>UT</b>	5.6	4.6, 6.4	10.0	9.1, 11	2.4	1.6, 3.5	5.7	90.5, 90.6	2.5	1.8, 3.4
<b>JS**</b>	<b>Sens</b>	3.2	1.3, 7.5	2.4	1, 5	64.9	63.4, 66.0	0.8	0.1, 4.1	31.7	27.3, 34.7
	<b>Spec</b>	97.8	97.7, 98	97.8	97.6, 98	99.2	98.8, 99.5	97.7	97.6, 97.8	99.6	99.3, 99.8
	<b>PPV</b>	7.3	2.9, 16.8	9.1	4, 19.3	95.5	93.1, 97.1	1.8	0.3, 9.4	81.8	70.4, 89.6
	<b>NPV</b>	95.0	94.9, 95.2	91.4	91.2, 91.6	91.5	91.1, 91.7	94.8	94.8, 95	95.9	95.7, 96.1
	<b>TO</b>	92.7	83.2, 97.1	90.9	80.7, 96	4.5	2.9, 6.9	98.2	90.6, 99.7	18.2	10.4, 29.6
	<b>UT</b>	5.0	4.8, 5.1	8.6	8.4, 8.8	8.5	8.3, 8.9	5.2	5, 5.2	4.1	3.9, 4.3
<b>CF</b>	<b>Sens</b>	48.4	43.4, 52.8	31.5	28.5, 34.1	19.5	16.9, 22.1	46.0	41.2, 50.2	44.2	39.4, 48.6
	<b>Spec</b>	98.8	98.6, 99.1	99.0	98.7, 99.3	98.3	98.0, 98.6	98.9	98.6, 99.1	98.7	98.4, 99
	<b>PPV</b>	70.5	63.2, 77	76.7	69.3, 82.9	59.7	51.5, 67.4	71.3	63.9, 77.8	68.2	60.7, 74.9
	<b>NPV</b>	97.1	96.8, 97.3	93.5	93.3, 93.8	90.5	90.2, 90.8	96.8	96.5, 97	96.7	96.6, 96.9
	<b>TO</b>	29.5	23, 37.8	23.3	17.1, 30.7	40.3	32.6, 48.5	28.7	22.2, 36.1	31.8	25.1, 30.3
	<b>UT</b>	2.9	2.7, 3.2	6.5	6.2, 6.7	9.5	9.2, 9.8	3.2	3, 3.5	3.3	3.1, 3.4

JS JumpSTART; CF Careflight; \* n=1020; \*\* n=2441



	START*		JumpSTART**		Careflight	
	%	95% CI	%	95% CI	%	95% CI
<b>Sens</b>	43.8	38.8,54.2	75.9	69.9,81.1	19.5	18,20.9
<b>Spec</b>	89.8	89.0,90.6	76.1	75.6,76.6	96.6	96,97.2
<b>PPV</b>	24.8	19.1,30.7	22.4	20.6,23.9	69.9	64.6,74.8
<b>NPV</b>	95.4	94.6,96.2	97.2	96.5,97.8	75.0	74.6,75.5
<b>OT</b>	75.2	60.3,80.9	77.6	76.1,79.4	80.5	75.1,85.4
<b>UT</b>	1.2	0.9,1.4	1.4	1.0,1.8	1.3	0.9,1.6

\* n=1020

\*\* n=2441

**Table A8.2: T2 results of other primary triage tools (% , 95% confidence intervals). n=3461**

	START*		JumpSTART**		Careflight	
	%	95% CI	%	95% CI	%	95% CI
<b>Sens</b>	76.3	73.4,79.0	74.1	72.5,75.8	74.6	73.1,76.0
<b>Spec</b>	46.7	43.9,49.4	35.9	33.9,37.9	40.0	38.4,41.6
<b>PPV</b>	58.5	56.3,60.6	58.2	56.9,59.5	58.5	57.3,59.6
<b>NPV</b>	66.7	62.6,70.5	53.6	50.6,56.5	58.1	55.7,60.5
<b>UT</b>	41.5	39.4,43.7	41.8	40.5,43.1	41.5	40.4,42.7
<b>TO</b>	33.3	29.5,37.4	46.4	43.5,49.4	41.9	39.5,44.3

\* n=1020

\*\* n=2441

**Table A8.3: T3 results of other primary triage tools (% , 95% confidence intervals). n=3461**

### **Paediatric Primary Triage Tools Compared to Other Triage Tools**

Comparison was made between the paediatric primary triage tools (PTT, Careflight, and START / JumpSTART) and the Triage Sieve. Analysis was also undertaken against the TRTS (used as part of the Triage Sort for secondary triage). The results for the adult tools with regard to T1 patients are shown at **table A8.4**; for

T2 patients, results are at **table A8.5**, and for T3, **table A8.6**. Direct comparison may be made with the results for the PTT and other primary triage tools in the corresponding tables.

	ISS		NISS		PTS		Garner		Delphi		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	
<b>SIEVE</b>	<b>Sens</b>	64.9	58.1, 71.1	49.0	43.9, 54.2	73.4	69.2, 77.2	31.5	25.6, 38.0	72.4	66.0, 77.9
	<b>Spec</b>	79.5	79.1, 79.8	79.7	79.2, 80.2	83.5	83.0, 84.0	77.4	77.0, 77.8	80.1	79.7, 80.4
	<b>PPV</b>	15.4	13.8, 16.8	19.4	17.4, 21.4	36.4	34.3, 38.3	7.9	6.4, 9.5	18.1	16.6, 19.5
	<b>NPV</b>	97.5	97.0, 98.0	94.0	93.4, 94.6	96.1	95.4, 96.6	94.8	94.4, 95.3	97.9	97.5, 98.4
	<b>OT</b>	84.6	83.2, 86.2	80.6	78.6, 82.6	63.6	61.7, 65.7	92.1	90.5, 93.6	81.9	80.5, 83.4
	<b>UT</b>	2.5	2.0, 3.0	6.0	3.4, 6.6	3.9	3.4, 4.6	5.2	4.7, 5.6	2.1	1.6, 2.5
<b>TRTS</b>	<b>Sens</b>	39.4	33.6, 45.2	25.8	22.0, 29.7	29.2	26.1, 32.1	7.0	4.2, 11.1	39.2	33.6, 44.5
	<b>Spec</b>	96.5	96.2, 96.9	96.6	96.2, 97.0	97.6	97.2, 98.0	94.7	94.5, 94.9	96.6	96.3, 97.0
	<b>PPV</b>	39.4	33.6, 45.2	43.1	36.8, 49.5	61.2	54.6, 67.4	7.4	4.5, 11.8	41.5	35.6, 47.4
	<b>NPV</b>	96.5	96.2, 96.9	92.9	92.5, 93.3	91.5	91.1, 91.8	94.3	94.1, 94.6	96.3	96.0, 96.6
	<b>OT</b>	60.6	54.8, 66.4	56.9	50.5, 63.2	38.8	32.6, 45.4	92.6	88.2, 95.5	58.5	52.6, 64.4
	<b>UT</b>	3.5	3.1, 4.8	7.1	6.7, 7.5	8.5	8.2, 8.9	5.7	5.4, 5.9	3.7	3.4, 4.0

JS                      JumpSTART  
 CF                      Careflight

**Table A8.4: T1 results, adult triage tools (% , 95% confidence intervals). n=3461**

	Triage Sieve		TRTS	
	%	95% CI	%	95% CI
<b>Sens</b>	31.9	27.2,36.8	36.2	31.1,41.7
<b>Spec</b>	93.5	93.1,93.9	82.5	82.0,83.0
<b>PPV</b>	29.8	25.5,34.4	15.2	13.0,17.5
<b>NPV</b>	94.1	93.7,94.5	3.7	93.2,94.3
<b>OT</b>	70.2	65.6,74.5	84.8	82.5,87.0
<b>UT</b>	1.3	1.0,1.6	5.1	4.1,6.0

**Table A8.5: T2 results, adult triage tools (% , 95% confidence intervals). n=3461**

	Triage Sieve		TRTS	
	%	95% CI	%	95% CI
<b>Sens</b>	74.8	56.8,59.1	81.0	79.6,82.5
<b>Spec</b>	38.5	93.1,93.9	30.6	29.1,32.14
<b>PPV</b>	58.0	25.5,34.4	56.9	56.0,57.9
<b>NPV</b>	57.4	93.7,94.5	58.6	55.7,61.5
<b>UT</b>	42.0	65.6,74.5	43.1	42.1,44.0
<b>OT</b>	42.6	4.5,6.3	41.4	38.5,44.3

**Table A8.6: T3 results, adult triage tools (% , 95% confidence intervals). n=3461**

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## **PUBLICATIONS FROM THESIS**

The following articles are derived from the work of this thesis, and were published as detailed below. Each of the authors has been approached for permission to reproduce the articles here, and such permissions have been forthcoming.

Reference ranges for respiration rate and heart rate in healthy children aged four to 16 years

LA Wallis, M Healy, MB Undy, I Maconochie *Archives of Disease in Childhood* 2005;**90**:1117-1121

Age related reference ranges of respiratory rate and heart rate for children in South Africa

LA Wallis, I Maconochie *Archives of Disease in Childhood* 2006;**91**:330-333

Validation of the Paediatric Triage Tape

LA Wallis, SD Carley *Emergency Medicine Journal* 2006;**23**:47-50

A Procedure-Based Alternative to the Injury Severity Score for Major Incident Triage of Children: Results of a Delphi Consensus Process

LA Wallis, SD Carley, TJ Hodgetts *Emergency Medicine Journal* 2006;**23**:291-295

Comparison of Paediatric Major Incident Primary Triage Tools

LA Wallis, SD Carley *Emergency Medicine Journal* 2006;**23**:475-478



## ORIGINAL ARTICLE

## Age related reference ranges for respiration rate and heart rate from 4 to 16 years

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See end of article for authors' affiliations

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**Background:** Clinical vital signs in children (temperature, heart rate, respiration rate, and blood pressure) are an integral part of clinical assessment of degree of illness or normality. Despite this, only blood pressure and temperature have a reliable evidence base. The accepted ranges of heart and respiration rate vary widely.

**Methods:** This study examined 1109 children aged 4-16 years in their own schools. Age, sex, height, weight, and resting respiration rate and heart rate were recorded. The data were used to produce age related reference ranges for everyday clinical use.

**Results:** Reference intervals are presented for the range of heart rate and respiration rate of healthy resting children aged 4-16 years. The recorded values are at variance with standard quoted ranges in currently available texts.

Clinical decision making relies on the history, examination, and results of selected investigations. As part of the general clinical examination, four vital signs are routinely recorded: heart rate, respiration rate, blood pressure, and temperature.

In order to derive clinically meaningful information for the paediatric patient, we must compare the vital signs recorded against a normal or reference range. Normal values for temperature are well established<sup>1</sup> and there is good evidence for normal values of blood pressure at various ages.<sup>2-4</sup> With regard to respiration rate (RR) and heart rate (HR), however, there is little evidence on which to base our "normal" values. Despite this, textbooks produce tables of reference values for various age groups, based on small numbers of patients. *Bates' guide to physical examination and history taking*<sup>5</sup> states that the normal values for RR in a newborn "should be 30-60, reducing to 20-40 in early childhood and 15-25 in older children". The same book states that the normal HR for a newborn should be 140, reducing to 115 between 6 months and 1 year, 110 between 1 and 2 years, 103 between 2 and 6, 95 aged 6 to 10, and 85 between 10 and 14 years. Both the *Forfar and Arneill*<sup>6</sup> and *Nelson*<sup>7</sup> textbooks also quote ranges of values.

These values produce widely differing ranges of what may be termed normal for healthy children. In a 1 year old, for instance, the range of RR values is from 25 to 60: a rate of 30 would be considered normal in some of these texts, while others consider this bradypnoea and recommend intervention.

In view of the lack of evidence behind the values that are commonly quoted, we undertook a study in Plymouth, UK, to investigate the reference ranges of heart rate and respiration rate in healthy, resting schoolchildren.

The aim of this study was to produce up to date reference ranges of heart rate and respiration rate for healthy resting children aged 4-16 years.

## METHODS

Plymouth was chosen as the site of the study as it is a fairly typical medium sized town, situated at sea level in the southwest of the UK. It has a population of 240 000 and a fairly typical socioeconomic mix.<sup>8</sup>

Ethical approval was obtained through the South Devon Local Regional Ethics Committee. Following sample size

calculations and estimates of likely consent rates, eight schools in Plymouth, Devon were approached; six agreed to take part in the study. The schools were chosen at random from lists of primary and secondary schools supplied by the local education board: four primary and four secondary schools were selected. Random number generation of subjects was undertaken by computer.

All children aged 4-16 years were asked to participate. After explanation to the children and their parents (in the form of a letter, and a presentation at the schools' assemblies), parental consent was sought for each child; in addition, children over 12 were asked to give their own consent. Children were excluded from the study if consent was refused or the form was not returned.

All children were seen in their school by a single investigator (LAW), in the presence of a female nurse chaperone. Children were brought out of their classrooms and left to sit quietly in a warm waiting area for 10 minutes.

The children then sat quietly in a warm, well lit classroom while their RR was measured by 60 seconds of direct observation of the clothed chest wall (by LAW). A partially completed breath in the 60 second time period was counted as a whole breath.

Each child then had their HR measured for 60 seconds using a Datex S5 Lite monitor. A finger probe was used in all cases. Recording did not commence until a suitable trace with a regular, pulsatile waveform was achieved continuously for 20 seconds. Data were transferred real time to a computer, using Datex software: recordings were made at 5 second intervals for 60 seconds. The mean of these recordings was registered as the child's HR.

Height and weight were recorded. Height was measured barefoot using a Leicester height measure: weight was also taken barefoot, with scales calibrated by the Department of Medical Physics at Derriford Hospital, Plymouth.

Children who were unwell on the day of the study (but were well enough to attend school) were still included in the sample, as were children with diagnosed or undiagnosed medical conditions. No attempt was made to identify these children in the database.

**Abbreviations:** HR, heart rate; RR, respiration rate

**Table 1** Distribution of sex and age

Age (y)	Boys	Girls	Total
4	27	22	49
5	39	30	69
6	43	57	100
7	35	38	73
8	46	42	88
9	20	56	76
10	40	23	63
11	68	42	110
12	55	107	162
13	43	65	108
14	36	59	95
15	28	28	56
16	28	32	60
Total	508	601	1109

### Statistical methods

Age was recorded as the age in years at the preceding birthday. The data were therefore treated as 13 separate frequency distributions, one for each year of age from 4 to 16. Preliminary analyses showed only small differences between the boys and girls in either HR or RR, and the data have been analysed for the two sexes together.

Calculation of the cumulant ratios<sup>27</sup> showed that the HR distributions were slightly skewed to the right. This was corrected for by logarithmic transformation. The means and standard deviations of the transformed data were calculated and smoothed by cubic and linear polynomials respectively. Upper and lower reference limits were calculated as mean  $\pm 1.96$  SD and back transformed.

The RR distributions were more irregular in shape, especially at the older ages where a "floor" effect at 10–11 bpm was evident. The empirical 2½ and 97½ centiles were calculated and smoothed by linear fits.

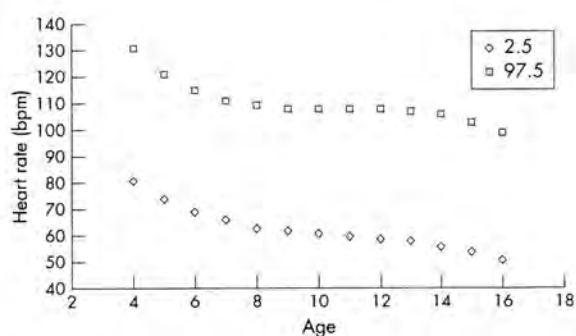
Details of the smoothing equations are provided in the Appendix.

## RESULTS

### Demographics

Six schools took part in the study, with a total of 3592 pupils. A total of 1153 children agreed to participate, but 44 failed to show to have their data collected. A total of 1109 children aged from 4 to 16 years were assessed.

The numbers of subjects and the spread of their ages are shown in table 1 (throughout these results, each year group refers to the period from the day of that birthday to the day prior to the next birthday).



**Figure 1** Heart rate by age (years) (2½, 97½ centiles). bpm, beats per minute.

### Height and weight

The mean heights and median weights of the population studied were plotted between the 50th and 75th centiles on the UK 90 Growth Charts for the United Kingdom.\*

### Respiratory and heart rate related to age

Using the methods described in the Appendix, the fitted reference values are shown in table 2. The values are shown as integers, rounded towards the median, with 95% reference interval (2½, 97½ centiles). The 2½ and 97½ centiles of HR and RR are shown plotted in figs 1 and 2.

### Respiratory and heart rate related to height and weight

The correlations of HR and RR with height and weight in each age group were calculated. All were small; the average correlations with height were  $-0.10$  for HR and  $-0.03$  for RR, while those for weight were  $-0.22$  for RR and  $-0.15$  for HR. The tendency towards negative values may reflect the negative trend of HR and RR as against the positive trend of height and weight with age within the age groups. There appears to be no case for considering height and weight in assessing HR and RR.

## DISCUSSION

### Evidence base

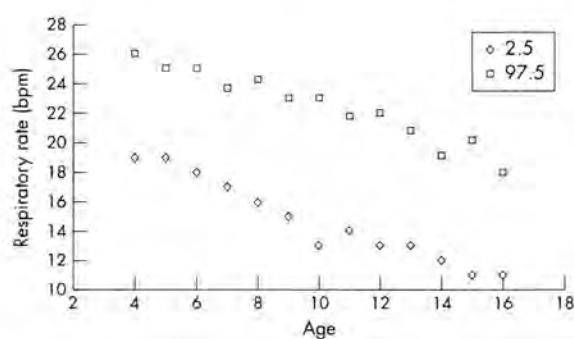
Most (although not all) clinicians agree that RR is a useful and important sign to measure.<sup>16</sup> However, there are little data to support the values that are given as "normal", and most cannot be considered applicable to healthy children in the developed world of the 21st century. Available studies fall

**Table 2** Respiration rate and heart rate; median and 2½, 97½ centiles by age

Age (y)	Heart rate (bpm)*			Respiration rate (bpm)†		
	2½	50	97½	2½	50	97½
4	81	103	131	20	22	26
5	74	95	121	19	21	25
6	69	89	115	18	21	24
7	66	85	111	17	20	24
8	63	83	109	17	19	23
9	62	82	108	16	19	23
10	61	81	108	15	18	22
11	60	80	108	14	17	21
12	59	80	108	14	17	21
13	58	79	107	13	16	20
14	56	77	106	12	15	20
15	54	74	103	12	14	19
16	51	71	99	11	14	18

\*Beats per minute.

†Breaths per minute.



**Figure 2** Respiratory rate by age (2½, 97½ centiles). bpm, breathes per minute.

into two groups: those looking at children who are ill or are attending an emergency department (ED), and those looking at RR of healthy children at rest.

There have been a number of studies in the first group. These give useful information, but none can be applied to healthy resting children. Morley and colleagues<sup>11</sup> studied babies up to 6 months of age who had signs of respiratory infection: data on older children with respiratory problems are in plentiful supply.<sup>12–14</sup>

In 1992, Hooker *et al* presented a series of 434 children presenting to an ED, concluding that RR was inversely proportional to age:<sup>15</sup> the data provided mean, standard deviation, and range values for each year from birth to 18 years. However, although children presenting with fever or primary cardiorespiratory symptoms were excluded, the study made no allowance for changes in RR due to pain, symptoms unrelated to the cardiorespiratory system, or simply the anxiety of being in a hospital ED. Furthermore, rates were recorded by different duty triage nurses, introducing an unquantifiable element of interobserver variability: this reduces the reliability of these measurements.<sup>16</sup>

The first available data on breathing rates in resting children came from Quetelet,<sup>17</sup> who studied the RR of 300 patients, including an unknown number of children at birth, 5 years, and 15–20 years. However, this was in 1835 and the data cannot be generalised to a modern setting: we do not know the sample size, their state of health, or where they came from. In 1952, Iliff and Lee<sup>18</sup> produced reference ranges for RR, but they measured only 188 children in total (birth to 18 years) and the children were either awake or sleeping, which leads to difficulties in interpreting the data. Furthermore, these children lived in Denver, Colorado at one mile altitude where the lower partial pressure of oxygen could have significantly influenced the results.

Cook and colleagues<sup>19</sup> and Nelson and colleagues<sup>20</sup> both published small data series (25–38 children) on children up to 1 month of age, but had no data on older children. In 1993,

Marks and colleagues<sup>21</sup> published a data set of 416 children from 1 to 7 years of age (293 awake, 123 sleeping). From these data, reference centiles were produced for RR both awake and asleep. There are two major limitations in their data. Firstly, although the children were at rest when they had their data recorded they were made to wear a nasal thermocouple to undertake the reading—there is good evidence that applying any form of mechanical device to measure respiratory parameters induces changes in the value recorded.<sup>22</sup> Secondly, although nasal thermocouples have been shown to be accurate in measuring RR,<sup>23</sup> this is not the method that is used in everyday clinical practice: we use direct observation, with or without a stethoscope.

The most reliable data on resting RR in children comes from Rusconi and colleagues,<sup>24</sup> who reported 618 children aged 15 days to 3 years, quietly resting or asleep. They had their RR measured by direct auscultation with a stethoscope for one minute. This data was used to produce age related centile curves. They found that:

- Respiration rate drops rapidly from birth to 3 months of age
- Respiration rate norms are widely spread for a given age, with most variation in the first three months of life.

From the available research, therefore, reference values for RR that are reliable and are of use in well children are only available up to 3 years of age.<sup>25</sup>

With regard to HR, once again there is scant evidence in support of the values that we accept for our day-to-day practice as “normal”. Available data regarding resting heart rates in children come from four main sources. All have limitations that prevent us extrapolating their data to healthy resting children in the UK of the 21st century.

In 1944 Shock produced data on resting HR in five boys and 50 girls aged between 11 and 17 years.<sup>26</sup> However, the children were examined in a laboratory while fasting; furthermore, the data represent only a small sample of a restricted age group, and measurements were made 60 years ago.

Iliff and Lee undertook measurement of HR in children aged between 1 and 18 years of age, both awake and asleep.<sup>18</sup> The sample size was only 197, with small numbers in each year group, and the data are now 50 years old. Furthermore, as previously mentioned, these children’s recorded values are likely to have been affected by the one-mile altitude at which they lived.

Data were collected in 1978 by Voors *et al* in Bogalusa, New Orleans, on 3590 resting schoolchildren aged 5–17 years, as part of a bigger epidemiological study.<sup>2</sup> These data were recorded in a hospital laboratory environment, which may have an unquantified effect on the HR recorded.<sup>27</sup> Their research efforts were concentrated on the epidemiology of hypertension, and the data on resting HR were only presented as unsmoothed centile charts: age ranges are not provided.

**Table 3** Evidence base for heart and respiration rate values

First author	Year	n	Age range	Comments
Quetelet <sup>17</sup>	1842	Unknown	Unknown	Unknown numbers and ages; 160 year old data
Shock <sup>26</sup>	1944	55	11–17	Small numbers; examined in laboratory; limited age range
Iliff <sup>18</sup>	1952	188	0–18	One mile altitude; children asleep and awake
Cook <sup>19</sup>	1955	25	0–1/12	Limited age range
Nelson <sup>20</sup>	1962	38	0–1/12	Limited age range
Voors <sup>2</sup>	1982	3590	5–17	No reference ranges presented; examined in laboratory
Marks <sup>21</sup>	1993	416	1–7	Measured by thermocouple; sleeping and awake
Rusconi <sup>24</sup>	1994	618	0–3	Limited age range

### What is already known on this topic

- Heart rate and respiratory rate vary in children in relation to age
- Age related ranges for respiratory rate are available up to 36 months of age

Dark and colleagues<sup>4</sup> have recently produced data on HR in 10 600 children of all ages: however, the study was aimed at producing reference ranges for injured and sick children, not a healthy population. Furthermore, data were taken from multiple hospitals over a period of ten years: this may introduce an unquantifiable degree of interobserver variation into the data collected.<sup>16</sup>

There is no reliable, contemporary evidence for resting heart rate in healthy children. These papers are summarised in table 3.

### Location of study

There is recent evidence that young Plymouth children (born in 1996–97, measured at age 24 months) are heavier than the standard UK centiles:<sup>27</sup> the mean difference from the centile chart was 0.33 standard deviations (460 g). These results may not necessarily be applicable to older Plymouth children (born pre-1996), who form the bulk of this study (the youngest children were aged 4 years, born in 1997). Furthermore, the absence of similar data from other UK towns does not mean that Plymouth is abnormal—these data may be fairly typical, but in the absence of further evidence this is not yet clear. However, population data suggest that Plymouth children may be considered fairly representative of children in the UK, albeit from a limited ethnic mix.

### Measurement technique

With regard to measurement of the physiological parameters, the method that was chosen was the one that most closely reflects our day-to-day practice.

### Respiration rate

Some authors have suggested that the most accurate way of recording RR is through the use of machinery such as a pneumogram.<sup>21</sup> However, this clearly does not reflect our day-to-day clinical practice. Furthermore, there is good evidence that the application of machinery to the child produces and increase in the RR.<sup>22</sup> This idea was therefore discounted.

The time period for measurement of the RR has been shown to be accurate<sup>28</sup> and is recommended by many sources, including *Bates' guide to physical examination and history taking*,<sup>3</sup> and the World Health Organisation.<sup>29</sup> Simoes and colleagues<sup>28</sup> showed that direct observation provides an accurate measurement of paediatric RR: they found a mean of 1.79 breaths per minute variation from the values recorded by pneumogram. Rusconi and colleagues<sup>21</sup> compared direct observation for 60 seconds with auscultation by stethoscope for the same time period. They found that the observed rate was a mean 1.8–2.6 breaths per minute lower than the auscultated rate. However, most practitioners routinely undertake RR measurement by direct observation, not auscultation, and so this method was employed in this study. Previous data have shown this method to be accurately repeatable.<sup>24</sup>

### Heart rate

In everyday practice, two methods are used to measure HR. The first is direct palpation of the radial artery at the wrist, a method that is widely practiced throughout the country. The

### What this study adds

- Data for heart rate and respiratory rate are provided for children who may be considered fairly typical of British schoolchildren
- Evidence based reference ranges of heart rate and respiratory rate for schoolchildren aged 4–16 years are provided

second method that is commonly employed is through electronic means of recording HR: this is now standard practice in EDs and wards (although not as common in primary care settings). The HR is often recorded at the same time as blood pressure and peripheral cutaneous oxygen saturations using a monitor. Previous research has shown that the rate recorded by this means correlates very closely with that recorded at the radial artery at the same time.<sup>30</sup>

There is good evidence that applying machinery to record RR alters the recorded rate:<sup>22</sup> there is no evidence of the presence or magnitude of a similar effect on HR. Although it is logical to extrapolate from Gilbert's work that an effect may be expected with regard to heart rate, there is a significant difference between the use of a device applied tightly to the face and an oxygen saturation probe applied to the finger. While we accept that this may have an effect on the HR recorded we believe that this will be no more significant than the effect of taking a pulse by palpation.

Electronic means (using a Datex S5 Lite monitor) were chosen to record this parameter, for ease of measurement, reliability, accuracy, and clinical relevance.

### Bias

Of 1153 children who agreed to participate in the study, only 44 did not attend the sessions: they either did not want to take part at the last minute (28), or were not at school on the day in question due to illness (n = 9) or other reasons (n = 7). It is accepted that children with chronic illness may have been deliberately withheld from the study, although what magnitude of effect this would have on the results, if any, is unclear.

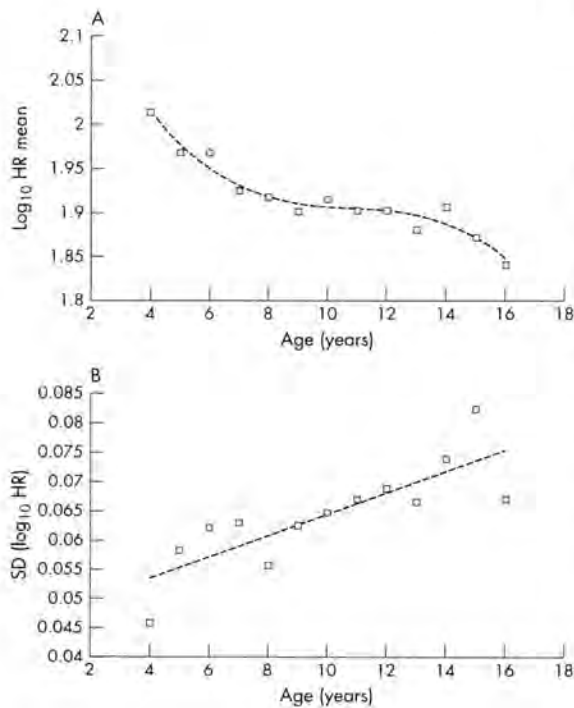
No attempt was made to identify those children with minor illness on the day of study: the fact that they were well enough to attend school should allow them to be considered as part of a normal, healthy population. Marks *et al* identified children with upper respiratory infections in their study, and found that although up to 49% of their patients had minor respiratory symptoms (most of their subjects were in child-care centres and kindergartens) this had no apparent effect on the respiration rate.<sup>21</sup>

### The reference ranges

The data are presented in table form (for simplicity of reference) as median and 95% reference interval (whole integers rounded towards the median). These figures differ significantly from the values quoted in common medical texts. This study provides evidence based reference ranges of HR and RR in healthy children, for day-to-day clinical use throughout the UK. However, we have not provided any data on children aged under 4 years, and there is a need for such ranges to be determined.

### Conclusion

This study has shown that the range of published "normal" values for heart rate and respiration rate varies widely depending on the source referred to, and has shown the lack of evidence behind these values.



**Figure 3** (A) Mean  $\log_{10}$  (heart rate) against age. (B) Standard deviation  $\log_{10}$  (heart rate) against age.

Reference ranges have been presented for respiration rates and heart rates in healthy schoolchildren aged between 4 and 16 years, at rest. Information regarding the relation of heart rate and respiration rate with height and weight has been presented. These children's height and weight fit closely to modern centile growth charts and they can therefore be taken as representative of "normal" schoolchildren.

There is a need for similar information to be made available from children aged under 4 years, although Rusconi *et al* have produced good data on respiration rates in this age group.<sup>14</sup> Data on heart rates in this age group are poor.

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#### APPENDIX

##### Heart rate

The fitted equations for the mean and SD of HR were:

- Mean  $\log_{10}(\text{HR}) = 1.941 - 0.003293 \times \text{age} + 0.000652 \times (\text{age} - 10)^2 - 0.0002861 \times (\text{age} - 10)^3$

- SD  $\log_{10}(\text{HR}) = 0.04745 + 0.001709 \times \text{age}$

(where "age" denotes age in years at last birthday).

The observed means and SDs with the fitted equations are shown in fig 3. If required, HR can be expressed as a z-score in the usual way by calculating  $(\log_{10}(\text{HR}) - \text{mean})/\text{SD}$ .

#### Respiratory rate

The fitted equations for the 2½ and 97½ centiles of RR were:

- 2½ centile =  $21.95 - 0.7239 \times \text{age}$
- 97½ centile =  $28.56 - 0.6051 \times \text{age}$

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## ORIGINAL ARTICLE

## Age related reference ranges of respiratory rate and heart rate for children in South Africa

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**Background:** The authors have recently presented reference ranges for heart rate and respiratory rate in healthy resting schoolchildren, aged 4-16 years, in the United Kingdom. There are no similar ranges for children in the developing world.

**Aims:** To undertake a study in Cape Town, South Africa, to establish whether the UK ranges may be applied to socioeconomically disadvantaged groups.

**Methods:** Data on 346 children in a township school were recorded; their height, weight, heart rate, and respiratory rate were compared to the UK ranges.

**Results:** The two groups plotted closely together by height and weight on the UK 90 growth reference charts. There was no difference in heart rate between the two groups, and a difference of 0.46 breathes per minutes in respiratory rate, which is not felt to be of clinical significance.

**Conclusion:** The reference ranges of heart and respiratory rate derived in the UK may be applied to children in developing world situations.

We have recently challenged the ranges of heart rate (HR) and respiratory rate (RR) that are quoted in medical texts<sup>1-3</sup> and life support courses,<sup>4</sup> citing the lack of evidence on which these ranges are based.<sup>5</sup> We derived reference ranges for RR and HR in healthy school children in the United Kingdom, aged from 4 to 16 years, and presented these as medians with 95% reference interval (2.5th, 97.5th centiles). While these ranges are helpful for children in the UK, by themselves they provide no information about the ranges of these values in other countries. One such country is South Africa, where many sectors of the paediatric population suffer from high rates of poverty, malnutrition, and chronic diseases (including HIV/AIDS).<sup>6-9</sup>

We undertook a study to determine whether the physiological ranges that we derived in the UK could be applied to socially disadvantaged schoolchildren in South Africa.

## METHODS

The Chris Hani Memorial School is a charity funded informal school in the Langa township (a historically disadvantaged area) of Cape Town. It educates 392 black children aged 5-16 years who have not had their birth registered and therefore are unable to enter the state school system.

The Ethics Board at the University of Cape Town (UCT) was approached for ethical approval. However, the Board's opinion was that ethical approval and consent were not required. Preliminary visits to the school by LAW allowed explanation of the project to the children and teachers. Letters were sent to all parents, offering them the opportunity to decline to allow their child to participate. No refusals were received.

## Data collection

All children were seen in their school by a single investigator (LAW), in the presence of a female nurse chaperone, in a one month period. Children were brought out of their classrooms and left to sit quietly outside the study room for five minutes.

The child sat fully clothed in a well lit classroom and their RR was counted over 60 seconds. They then had their HR measured for 60 seconds using a Datex S5 Lite monitor. A

finger probe was used in all cases. Recording did not commence until a suitable trace with a regular, pulsatile waveform was achieved continuously for 20 seconds. Data were transferred real time to a computer, using Datex software: recordings were made at 5 second intervals for 60 seconds. The mean of these recordings was registered as the child's HR. Ambient temperature was recorded in the room at the same time.

Children then had their standing height recorded using a Leicester height meter, and weight using analogue metric scales calibrated by the department of medical physics at the Red Cross Children's Hospital. All equipment was the same as had been used in the UK arm of the study.

Children who were unwell on the day of the study (but were well enough to attend school) were still included in the sample, as were children with diagnosed or undiagnosed medical conditions. No attempt was made to identify these children in the database.

## Data analysis

The heights and weights of the children were plotted on the UK 90 growth charts,<sup>10</sup> to determine whether they could be considered to be similar to a UK population. Each plot was at the mid point of that year on the centile chart (that is, the median weight for 6 year olds was plotted at 6.5 years on the chart). Height was plotted as mean value, and weight as median.

For the physiological values at each age, median, inter quartile range (IQR), and range were derived and plotted against the reference ranges derived in the UK.<sup>6</sup> Age was considered to be age in years at the last birthday. The data were therefore considered as 12 separate frequency distributions, from 5 to 16 years (the 4 year old age group in the UK was ignored for these analyses). Two way analysis of variance was undertaken to determine any difference in the values of each of these parameters between the two countries. Analysis was undertaken on SPSS software.

**Abbreviations:** HR, heart rate; RR, respiratory rate

**Table 1** Age and sex distribution (n = 346)

Age (y)	Male	Female	Total (%)
5	15	13	28 (8.1)
6	21	20	41 (11.9)
7	9	15	24 (6.9)
8	12	12	24 (6.9)
9	6	14	20 (5.8)
10	13	10	23 (6.7)
11	22	16	38 (11.0)
12	13	13	26 (7.5)
13	16	13	29 (8.4)
14	16	17	33 (9.5)
15	8	20	28 (8.1)
16	13	19	32 (9.3)
	164	182	

## RESULTS

All children who were present on the days of data collection took part in the study—a total of 346 (88%). None of the children were known to have any medical conditions. Table 1 shows the age and sex distribution; 182 were female (52.6%). Table 2 shows the age ranges and means. The smallest group was the 9 year olds (n = 20); the number of 6 year olds was 41.

The mean ambient temperature was 25°C. The UK sample had failed to show a relation between the ambient temperature and the physiological values, and no relation was evident in this sample.

### Height and weight

The height and weight of both sexes plotted mostly between the 25th and 50th centiles of the UK 90 growth reference charts. In girls, 15 and 16 year olds approached the 75th centile for height and weight. Boys showed similar curves, but at a slightly lower centile: for weight, they tracked towards the 25th centile until the older age group, where 14–16 year olds touched the 50th centile. Boys were slightly shorter than girls, plotting close to the 25th centile through out all ages.

### Heart and respiratory rate

Table 3 shows the median HR and RR. They are plotted, with IQR and range, against UK centiles in figs 1 and 2.

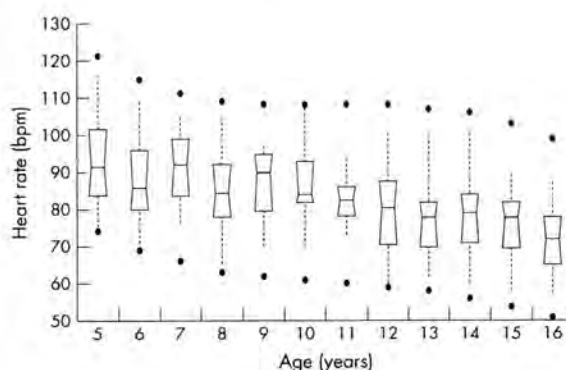
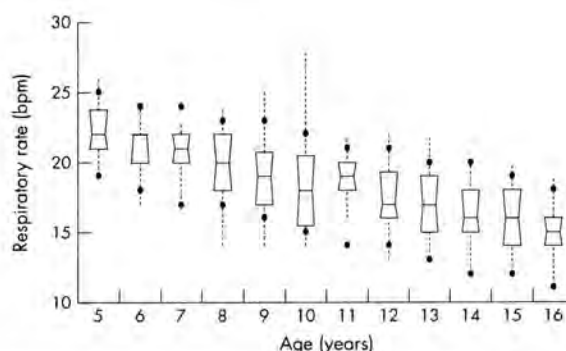
Two way analysis of variance was undertaken, and showed that there was no significant difference between the groups by HR ( $p = 0.286$ ). With regard to RR, there was a significant difference, with the South African children having a mean 0.42 breaths per minute higher RR than their UK counterparts ( $p < 0.0005$ ); this difference was minimal under age 10, and almost 0.9 bpm after age 10 years.

## DISCUSSION

All children in this study live at sea level, therefore there will be no effect of altitude on these results. The study sample live in one of the poorest areas of Cape Town; while no attempt has been made to quantify the socioeconomic status, it is reasonable to state that these children are from a deprived

**Table 2** Group size; range, mean, and median in each one year age group (n = 346)

	Male	Female	Total
Range	6–22	10–20	20–41
Mean	13.7	15.2	28.8
Median	13.0	14.5	28.0

**Figure 1** Heart rate (beats per minute) versus age; South Africa median, IQR, and range against UK 2.5th, 97.5th centiles.**Figure 2** Respiratory rate (breaths per minute) versus age; South Africa median, IQR, and range against UK 2.5th, 97.5th centiles.

background. However, the school that they attend is charity funded and may, therefore, provide a degree of poverty alleviation not seen by many children in this country.

### Height and weight

The growth of children in parts of the developing world has been studied extensively,<sup>11–17</sup> as has the change in growth of such children when they emigrate to more advanced nations.<sup>18–21</sup> With some minor ethnic variation, such children typically adopt the growth patterns of their adopted country. Socioeconomic status, not ethnic origin, is believed to be the major determinant of growth.<sup>11, 22–25</sup> Growth is also known to be adversely affected by the presence of chronic medical conditions.<sup>22, 24, 25</sup> The UK sample in this study failed to show a relation between height or weight and the HR or RR; similarly, there was no relation evident in this sample.

It was hoped to plot the South African children against a larger cohort of height and weight data from that country. However, no such data were available at the time of this study. The paediatric growth charts in current use are based on American values.

The children in this study are socially disadvantaged and have a high incidence of chronic medical conditions.<sup>7, 8</sup> Despite this, they lie between the 25th and 50th centiles of the UK 90 growth reference standards (although these standards for weight may now be incorrect with the increase in obesity in UK children<sup>26, 27</sup>), being slightly smaller and lighter as a whole than their UK peers.

### What is already known on this topic

- Reference ranges for heart rate and respiratory rate have been derived for healthy UK children
- Similar data do not exist throughout the developing world

In the UK sample on whom the current RR and HR reference ranges were derived,<sup>6</sup> both sexes plotted between the 50th and 75th centiles for height and weight (with girls being slightly taller and heavier). As both samples plot close together around the 50th centile of the UK 90 charts, they may be considered similar enough by growth to undertake further physiological analysis between the two groups.

### Respiratory rate and heart rate

With regard to HR and RR, there are no current reference ranges for children in South Africa (or in the developing world generally). There are some data on RR in children with a variety of acute medical conditions, most notably respiratory infections<sup>20</sup> or malaria.<sup>21</sup> However, these are of no help in determining reference values for "normal" healthy children.

This study compared the measured HR and RR to the reference ranges for 4–16 year old UK children. With regard to HR, there was no difference between the two groups: there are up to four beats per minute differences at the extremes of age, but these occur in opposite directions, and are not felt to be clinically significant at this level. For RR, a significant difference exists, with the South African children having a mean 0.42 breaths per minute higher RR than the UK group (becoming most apparent after 10 years of age where it is over 0.8 breaths per minute). This difference is statistically, but not clinically, significant; measurement of less than one breath per minute is not possible and, pragmatically, the two groups may be considered to have identical RR.

It is accepted that measurement over a one minute period may miss some of the minute to minute variation in the values of HR and RR in these children. A sample of just under 10% of the study group ( $n = 32$ ) had their measurements repeated after 5 and 10 minutes: there were no significant differences in the values recorded in these children at any of these times (RR varied by a mean of under 1 bpm; HR less than 5 bpm).

This population of South African children may be considered to share the same reference range of HR and RR as those studied in the UK; these ranges are shown in the figures and have recently been published.<sup>6</sup> The ranges are applicable at sea level.

**Table 3** Heart and respiratory rate medians, South African children ( $n = 346$ )

Age (y)	Heart rate (bpm)*	Respiratory rate (bpm)†
5	91	22
6	86	22
7	92	21
8	84	20
9	90	19
10	84	18
11	82	19
12	80	17
13	78	17
14	79	16
15	78	16
16	72	15

\*bpm, beats per minute; †bpm, breaths per minute.

### What this study adds

- Reference ranges for heart rate and respiratory rate for socioeconomically deprived children in South Africa have been derived

### Conclusion

This paper has compared the RR and HR of schoolchildren aged 5–16 years in two distinct populations: a South African township and UK city. We have established that, despite their socioeconomic and health disadvantages, the resting physiology of the South African children is no different to the UK derived reference ranges. These reference ranges may be used as the "normal" ranges of healthy 5–16 year old children at rest.

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## ORIGINAL ARTICLE

## Validation of the Paediatric Triage Tape

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**Introduction:** The Paediatric Triage Tape (PTT) is an easy to use major incident primary triage tool, based upon a modification of the Triage Sieve. The purpose of this study was to prospectively validate the PTT for use in paediatric major incidents.

**Methods:** A database of children presenting the Trauma Unit of the Red Cross Children's Hospital, Cape Town, was developed over a nine month period. Each child was triaged using the PTT, and had an Injury Severity Score (ISS) calculated. Additionally, the New Injury Severity Score (NISS) was calculated, and the presence of interventions that may occur to the children ('Garner criteria') was documented. The sensitivity, specificity, overtriage, and undertriage rates were calculated.

**Results:** 3461 children were entered into the database. For identifying children with an ISS of over 15, the PTT had a sensitivity of 37.8%, specificity of 98.6%, overtriage rate of 38.8%, and an undertriage rate of 3.5%. Against the NISS and Garner criteria, the results were comparable.

**Conclusion:** The PTT has poor sensitivity at identifying immediate priority children by these criteria. Specificity (the ability to identify non-T1 patients) is excellent, and the overtriage and undertriage rates are within the range deemed unavoidable by the American College of Surgeons.

Although originally developed for use in military conflicts, triage is equally applicable to civilian major incidents. It is a key component of medical support during a major incident,<sup>1</sup> and allows an unmanageable task to be divided into component parts. There are numerous triage systems that exist for use on a day to day basis, both prehospital and in-hospital. A number of these have been modified to produce triage systems for use in major incidents.<sup>1,2</sup> During major incidents, different systems are typically applied for primary and secondary triage. Primary triage is a very rapid 'first look', quickly categorising patients by simple discriminators. The simplest and fastest systems tend to be based on easy to identify parameters that can be detected by personnel with any degree of training. For example, in many systems the ability to walk leads to automatic triage as T3. In addition to such items, physiological parameters are typically used in primary and secondary triage schemes, as they are reproducible to measure and are not dependant upon operator experience. Such physiology generally involves respiratory rate and heart rate, although capillary refill time is occasionally advocated (as in the Triage Sieve<sup>3</sup>).

Whichever triage system is used, all healthcare resources at the scene must use it. Furthermore, the system must be easy to teach (so that inexperienced personnel can quickly adopt it and use it at the scene), fast to perform, and accurate (it must identify those patients who are seriously injured as well as those who are less so).

There are specific concerns about the triage of children in major incidents: these have often been raised in major incident case reports<sup>4</sup> and it is a commonly expressed concern on major incident management courses.<sup>5</sup> These concerns have been directed at the effectiveness of adult based triage tools to accurately triage children. Most major incident triage systems are based on adult physiology: if these values are applied to small children then there will be an artificially high triage priority assigned. Although this may be thought of as a useful thing (so that children are removed from the scene at the earliest opportunity), it is likely that paediatric resources (both at the scene and at hospital) will be limited and will risk becoming overwhelmed by



**Figure 1** The Paediatric Triage Tape. The tape is placed next to the child from the head end. The algorithm next to the child's feet is then used to triage the child.

inappropriately triaged children. This can lead to genuine cases not receiving the care that they require: Frykberg showed a clear relation between increasing overtriage and increasing mortality.<sup>6</sup>

In order to help overcome this problem, a child specific major incident triage tool is needed. One such tool that is currently available is the Paediatric Triage Tape (PTT)<sup>7</sup> (see fig 1), in use throughout the UK and many other countries. It is a vinyl waterproof tape, derived from, and using exactly the same flow process as, the Triage Sieve. It has specific triage blocks for children measuring <50 cm, 50-80 cm, 80-100 cm, 100-140 cm, and >140 cm. It has not yet been validated.

Two other specific paediatric primary triage tools are in common use: JumpSTART<sup>8</sup> methodology is used throughout much of the United States, while Careflight<sup>9</sup> is used in many parts of Australia. Neither tool has been validated for use in children, and there is no evidence which of these tools is the best to use in a major incident.

**Abbreviations:** ACSCOT, American College of Surgeons Committee on Trauma; ISS, Injury Severity Score; NISS, New Injury Severity Score; PIT, Paediatric Triage Tape.

**Table 1** Garner criteria

Operative intervention	(Non-orthopaedic; within 6 hours)
Fluid resuscitation	(1000 ml or more, to maintain BP >89 mmHg)
Invasive CNS monitoring	(Or a positive head CT scan)
A procedure to maintain the airway	(Or assisted ventilation)
Decompression of a tension pneumothorax	

### Validation of triage tools

Triage tools are traditionally validated against the Injury Severity Score (ISS<sup>9</sup>). However, the New Injury Severity Score (NISS)<sup>10</sup> may be more accurate as it measures the three worst injuries in any body region, rather than using the highest score in each of three different body regions.<sup>11</sup> Whichever of the two systems is chosen, there are limitations in applying it against major incident triage algorithms; both tools are only designed to identify major trauma patients (those who are T1 (immediate), or not-T1) and have no discriminatory value between T2 (urgent) and T3 (delayed) patients; they have only been shown to accurately predict death; they focus on injury pattern and not the requirement for medical intervention (the main drive behind triage at a major incident); and they are of no help in assessing the triage of non-injured (medical) patients.

An alternative solution has been proposed by Baxt and Upnekies,<sup>12</sup> later modified by Garner *et al*<sup>13</sup> to be applicable to major incident situations: they proposed that specific interventions rather than injury scores should be used as the determinants of outcome and hence triage category. The criteria used by Garner *et al* are shown in table 1.

Although these criteria were designed for comparison of adult major incident triage schemes, they may be applied (with simple modification) to children. The requirement for fluid resuscitation (>1000 ml) may be modified to the requirement for resuscitation of over 20 ml/kg of fluid (in excess of the first fluid bolus recommended by the Advanced Paediatric Life Support Course<sup>14</sup>).

For the purposes of this article, the validation of the PTT will occur against the ISS, with concurrent comparison to NISS and Garner criteria (modified for children, but simply referred to as modified Garner criteria throughout this article). The aim of this article is to validate the PTT as a major incident primary triage tool.

### METHODS

The Trauma Unit of the Red Cross Children's Hospital, Cape Town, sees children aged up to 12 years. As the major tertiary referral centre for the Cape Town area, it receives approximately 9000 injured children each year. Over nine months of 2002, a prospective database of attendees was compiled, as the basis for the validation of the PTT.

Children were considered eligible for enrolment in the study if they were aged under 13 years and presented within 12 hours of an acute injury.

**Table 3** Primary data for table 2

	PTT triage			Total
	T1	Not-T1		
ISS	16+	71	117	188
	<16	47	3226	3273
	Total	118	3343	3461
NISS	16+	82	232	314
	<16	36	3111	3147
	Total	118	3343	3461
Garner	Yes	83	117	200
	No	35	3226	3261
	Total	118	3343	3461

Children were triaged on arrival at the Trauma Unit, using the PTT, as T1, T2, T3, or Dead using either their initial assessment in the trauma unit, or data as recorded on arrival at the scene if brought by paramedics. All children were prospectively followed through to death or discharge. Each child had an ISS and NISS determined. Data were recorded concerning the presence of any of the modified Garner criteria.

The sensitivity, specificity, overtriage, and undertriage rates of the PTT were calculated against ISS, NISS, and modified Garner criteria. Sensitivity reflects the proportions of those patients who are T1 who are correctly identified as T1; specificity is the proportion of patients who are not-T1 who are correctly identified as not-T1; the overtriage rate represents the proportion of patients who are triaged T1 but are not-T1, and undertriage represents the patients who are identified as not-T1 who actually are T1.

### RESULTS

In the study period, 5508 children presented to the Trauma Unit within 12 hours of injury. Of these, 3597 children met the entry criteria for the study: 3461 (96%) children were enrolled onto the database (see fig 2). Sixty three per cent were male, with a median age of 7 years.

There were 188 (5.4%) with an ISS of 16+, 314 (9.1%) with NISS 16+, and 312 Garner criteria were present in 200 (5.8%) children. For each of these standards, the sensitivity, specificity, overtriage, and undertriage rates for the PTT overall are presented in table 2. The primary data from which these calculations were made is shown in table 3. Table 4 shows the breakdown of these results for each height block.

Only five children were under 50 cm, and all were triaged T1 in accordance with the PTT's instructions. All had an ISS under 16, NISS under 16, and none had any Garner criteria present.

### DISCUSSION

An ideal triage tool will correctly spot all T1 patients (high sensitivity); however, the higher the sensitivity the lower the specificity (the ability to correctly spot patients who are not-T1) resulting in more patients being directed for immediate care, and risking swamping medical resources. In a major incident, a high degree of specificity is essential.

**Table 2** PTT: results by ISS, NISS, and presence of one or more Garner criteria

	ISS (%)	95% CI	NISS (%)	95% CI	Garner (%)	95% CI
Sensitivity	37.8	32.7-42.5	26.1	23-28.8	41.5	36.8-45.6
Specificity	98.6	98.3-98.8	98.9	98.5-99.1	98.9	98.6-99.2
Overtriage	38.8	32.3-47.9	30.5	23.2-38.8	29.5	22.7-37.5
Undertriage	3.5	3.2-3.8	6.9	6.7-7.2	3.5	3.3-3.8

**Table 4** Height blocks of PTT: results by ISS, NISS, and presence of one or more Garner criteria

Height block (cm)		ISS (%)	95% CI	NISS (%)	95% CI	Garner (%)	95% CI
50-80	Sensitivity	21.7	11.3-27.9	16.1	8.3-20.7	25	13-32.1
	Specificity	99.6	99.1-99.9	99.6	99.1-99.9	99.6	99.1-99.9
	Overtriage	28.6	8.4-62.9	28.6	8.3-63.3	28.6	8.4-62.8
	Undertriage	3.4	3.2-3.9	5	4.7-5.4	2.9	2.6-3.3
80-100	Sensitivity	20	12-27.6	19	12.4-24.1	23.6	16.6-27.9
	Specificity	99	98.6-99.4	99.3	98.8-99.6	99.5	99-99.8
	Overtriage	47.1	27-67.2	35.3	17.7-57.8	23.5	9.7-46.2
	Undertriage	3.3	3.9-4.7	5.6	5.2-6.0	5	4.7-5.4
100-140	Sensitivity	50.6	42.4-57.9	30.5	26.1-34	54.7	47.4-60.8
	Specificity	98.2	97.8-98.6	98.7	98.2-99.1	98.7	98.3-99.1
	Overtriage	38.9	30-42.8	26.4	17.9-36.8	27.8	19.8-37.4
	Undertriage	2.7	2.3-3.2	7.56	7.2-8.1	2.7	2.3-3.1
>140	Sensitivity	39.4	28.2-46.4	25.5	18-30.1	43.3	31.2-51
	Specificity	98.9	97.9-99.5	98.9	97.8-99.5	98.9	98-99.5
	Overtriage	23.5	8.9-45.2	23.5	9.7-46	23.5	10-44.5
	Undertriage	5.2	4.6-6.1	9.8	9.2-10.8	4.4	3.8-5.3

The American College of Surgeons Committee on Trauma (ACSCOT) states that triage tools will have an unavoidable undertriage rate of 5-10%, associated with an overtriage rate of 30-50%.<sup>15</sup> Excessive overtriage of children may be seen to be beneficial, to quickly remove them from the scene, but risks swamping limited paediatric resources. Undertriage results in missing those children who need immediate care: both undertriage and overtriage must be minimised.

### Principal findings

The PTT was found to have poor sensitivity against ISS, NISS, and Garner criteria, indicating that it does not detect all of the T1 patients. Part of the explanation for this may lie in the very high specificity (up to 98.9%): the PTT is excellent at identifying patients who are not-T1, but poor at identifying those who are T1. The undertriage and overtriage rates against all three gold standards were within the recommendations of the ACSCOT report.<sup>15</sup>

No height block was more predictive than the PTT overall. Only five children were under 50 cm in length, and all were triaged T1. It is unlikely that a large enough sample of injured children of this size will ever be achieved in order to make meaningful conclusions (as they are unlikely to be out of hospital at this size). However, the current practice of triaging these children as T1<sup>1</sup> is likely to be safe as it removes this difficult group from the scene rapidly, and represents a tiny proportion of any likely patient load that will be potentially overtriaged.

### Strengths and weaknesses of the study

A 12 hour cut off for entry into the study may be considered to be excessively long (although there are no data concerning the time to presentation for casualties in major incidents in the UK). Although this may be true in areas with rapid access to and assessment of casualties, there is no guarantee that this will be the only place in which the PTT has the potential to be used. It is well known that casualties in larger major incidents, remote incidents, and in incidents occurring in less well developed countries (for example in South Africa) that the time from injury to assessment will be longer than is typically the case in normal day to day European practice. We therefore chose the time limit of 12 hours as an arbitrary cut off that we felt represented patients who attended hospital as a result of their primary injury rather than as a result of a secondary deterioration from an initial injury.

Although this study was designed to prospectively assess the utility of the PTT, the number of patients enrolled with an ISS of 15+ is relatively small, especially in some of the height

blocks, producing results with wide confidence intervals. However, as the majority of patients from a major incident are likely to be minor in nature,<sup>16</sup> the patient distribution in this study is representative.

Choosing to validate a UK based triage system in a developing country may lead to bias in the conclusions, as the physiological parameters used by the tool may be different in that country. Work undertaken by one of the authors (LAW, in press) shows that the heart rate and respiratory rate of children in the UK and South Africa are identical by height or weight (although not by age, as children in South Africa are smaller and less heavy at any given age). Hence, direct extrapolation of the results to the UK population is possible.

One of the gold standards chosen for this study (Garner criteria) was developed as expert opinion, and has not been validated as an outcome measure for a triage tool. Furthermore, these criteria were developed to test adult based triage tools.<sup>17</sup> However, they highlight some of the common interventions that a patient may require following injury in a major incident, and these criteria may equally be applied to children as well as adults.

The ability to identify patients as T2, T3, or dead cannot be measured with current gold standards.

### Strengths and weaknesses in relation to other studies

There have been no other studies attempting to validate major incident primary triage algorithms in children. However, Garner *et al* reported much higher sensitivities in their analysis of adult primary triage tools (82-85%).<sup>17</sup>

### Meaning of the study

The PTT is known to be easy to learn, fast, and easy to use:<sup>18</sup> these properties are very favourable in major incident primary triage algorithms. This study shows that the PTT is a poor tool to identify seriously injured children (although the utility of this outcome in a major incident setting is of doubt).

### Unanswered questions and future research

Whichever triage algorithm is used, it should be validated in conditions as close as possible to those in which it is used. This is unlikely to ever occur in the setting of a major incident, due to the very nature of these incidents. Computer modelling and major incident registries may help in this regard in the future. However, the only widely accepted gold standard currently available for testing triage algorithms is the ISS. The NISS is felt by many to be superior to the ISS as

it incorporates data from the three worst injuries sustained:<sup>11</sup> it is yet to gain wide acceptance as either a triage algorithm validation tool or a trauma system analysis tool (the main current use of ISS).

The use of an ISS of 16 or higher as a marker of major trauma is well established in regionalised systems of health care such as the USA. As this level of ISS is associated with worse outcomes, it is appropriate to use ISS 16+ as a marker of those patients who should be identified as immediate (T1) in a major incident setting. The same argument holds well for NISS of 16+. However, the group of patients with an ISS (or NISS) of 14 or below may contain some people who should be triaged as T2 (urgent) and some T3 (delayed). Neither ISS nor NISS allows for differentiation between these groups. For this reason, it is appropriate to use ISS/NISS 16+ as a marker of immediate priority, but an ISS of 15 and below is of no discriminatory value.<sup>12</sup>

Furthermore, in a major incident it is not the severity of specific injuries that is of importance when undertaking primary triage, but rather the requirement for medical intervention. The ISS/NISS are not measuring outcomes that are helpful in major incident setting. This problem is overcome by the use of Garner criteria, which identify patients in need of specific interventions. However, like ISS/NISS these criteria may only be used to identify those patients to be triaged T1 (immediate), with no discriminatory value for not-T1 patients.

Altering the physiological parameters used on the PTT to identify a change in triage category is an essential next step. This is currently being researched in Cape Town and is likely to require modification of the respiratory rate and heart rate values for each of the height blocks. Once this analysis is completed the new algorithm may then be prospectively validated.

## CONCLUSION

The PTT is a simple to use tool for primary triage at major incidents. As it is based upon the Triage Sieve, it should be easy for most practitioners in the UK to become familiar with its use.

It has good undertriage and overtriage rates, and excellent specificity although sensitivity is poor (it only correctly identifies less than half of all T1 patients, meaning that many seriously injured children will not be detected by this tool). The reason behind this may lie in the ranges of physiological values at which triage category changes. Work is currently underway to modify these values in order to increase the sensitivity of the PTT, although it is accepted that this will inevitably be at the expense of less specificity.

In the meantime, in areas where the PTT is currently used we recommend its ongoing usage pending redesign, as any problems with sensitivity may be outweighed by the problems of learning a new tool.

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## ORIGINAL ARTICLE

## A procedure based alternative to the injury severity score for major incident triage of children: results of a Delphi consensus process

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**Background:** Triage at the site of a major incident is key to effective scene management. A number of triage algorithms have been suggested to assist the triage officer to determine triage priorities. However, many advocated scores were not specifically developed for use in major incidents, nor are they designed for multiple age groups.

Many of these algorithms have not been validated: those that have were validated against the Injury Severity Score, which is of little relevance in a major incident—it is the urgency of medical intervention that is of importance in this setting.

**Objectives:** To develop a set of criteria against which major incident triage algorithms can be tested.

**Methods:** Sixteen experts from the UK and South Africa took part in a three round Delphi consensus method in order to develop clinical criteria against which major incident triage algorithms may be tested.

**Results:** Thirty nine statements were initially identified as possible determinants of triage priority: 29 statements reached consensus. These associate specific clinical interventions with triage priority.

**Conclusion:** Delphi may be used to identify which clinical criteria define triage priority in a major incident setting. These criteria and the associated triage categories may be used as for the validation of specific major incident triage algorithms. This method may be used to develop specific criteria for other triage algorithms.

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For the health services, a major incident may be defined as "an event that owing to the number, severity, type or location of live casualties requires special arrangements by the health services".<sup>1</sup> Triage is an essential component of successful major incident management. It occurs in two phases: primary triage, at the scene, is a rapid "once over" to quickly identify those patients in need of immediate intervention and those who can wait for longer; secondary triage occurs at the location of the main treatment centre, where time and resources allow for a more in depth triage process.

Triage is designed to differentiate patients in terms of how unwell they are and how urgently they may require care. The potential for over triage of injured patients may put unnecessary pressure on limited medical resources. Similarly, under triage (where patients with serious injury are missed) must also be avoided for obvious reasons. Although it is ideal for a triage algorithm to act as a perfect discriminator, realistically this is not possible.

It is also important to clearly understand the purpose of a major incident triage algorithm, which is to only discriminate patients into categories that relate to the urgency of clinical intervention. The severity of injury sustained, or the specific injury patterns, are of secondary importance at the scene of a major incident.

Previous studies on triage scores have used final anatomical injury, physiological derangement, or both, to determine their accuracy and validity.<sup>2–4</sup> Inevitably this is a circular argument as all scores use anatomical and/or physiological data in their calculation. The use of the Injury Severity Score (ISS)<sup>5</sup> as the main tool against which most of these studies have been performed is also flawed: ISS bears little relation to the urgency of requirement for medical intervention at the scene of a major incident.

None of the major incident primary triage tools currently available have been formally validated, for ethical and practical reasons.

### AIM

We sought to develop a set of criteria that form a procedure based outcome tool that may be used in place of the ISS in the major incident setting: this tool may then be used for the future testing of major incident triage algorithms (specifically, for this study, the Paediatric Triage Tape<sup>®</sup>).

We have described the derivation of these criteria in order that they are available to other researchers in the field.

### METHOD

A three round Delphi study was used to determine clinical conditions and interventions that could be used as alternative outcome markers for studies of major incidents.

The initial Delphi process consisted of the authors identifying experts in major incident triage. The experts were selected to include specialists in major incident management and planning, or emergency care. Twenty were approached to take part in a three round Delphi study: 16 agreed.

Participants were selected from the work locations of the authors: the UK and South Africa. They were chosen for recognised expertise in the field of major incidents, and represented the Ambulance Service, Immediate Care, Emergency Medicine, Paediatric Emergency Medicine, General Paediatrics, Emergency Medical Services, Paediatric Trauma, Paediatric Surgery, and Paediatric Intensive Care.

**Abbreviations:** CNS, central nervous system; CT, computed tomogram; ISS, Injury Severity Score

A single author (LAW) undertook the Delphi process and collected and analysed all data on a Microsoft Excel<sup>®</sup> spreadsheet.

### The Delphi process

#### Round 1

Delphi group members were asked to identify clinical interventions that may occur to patients injured in a major incident. These interventions were collated and summarised into a single document for presentation at round two.

#### Round 2

Thirty nine interventions were identified in round one (table 1). These were sent to all group members who were then asked to determine the appropriate triage category for that patient—for example, what category should a triage score classify a patient who requires a needle cricothyrotomy OR needs a laparotomy within an hour. The accompanying text can be found in the appendix.

Group members were required to indicate whether they would triage each item as Priority T1 (immediate), T2 (urgent), T3 (delayed), or dead. The expectant category was not considered in this Delphi. Items reaching consensus (80% group agreement) were not reiterated in round three.

**Table 1** Group derived list of clinical interventions

Intervention
1 Blood within 30 minutes of arrival at ED
2 Cardiac arrest protocol (pulse present on first triage)
3 Chest drain insertion
4 Cricothyrotomy
5 CT abdomen/chest within 1 hour of arrival
6 CT head within 1 hour of arrival
7 Direct pressure to control severe haemorrhage
8 DPL or FAST ultrasound in ED
9 Escharotomy in ED
10 External pelvic fixation within 1 hour
11 Fluid resuscitation in excess of 20 ml/kg
12 Intravenous analgesia in ED
13 Intubation and ventilation (unless non emergent—for example, CT)
14 Laryngeal mask airway (unless non emergent)
15 Long bone splint application (femur)
16 Long bone splint application (lower leg)
17 Nasopharyngeal airway insertion for airway protection
18 Needle cricothyrotomy
19 Needle thoracocentesis
20 Opiate analgesia (not intravenous)
21 Oropharyngeal airway insertion for airway protection
22 Pericardiocentesis
23 Plaster of paris application (forearm)
24 Plaster of paris application (long arm)
25 Plaster of paris application (long leg PoP)
26 Simple dressing application
27 Sling application
28 Sutures
29 Tourniquet to control severe haemorrhage
30 Need a laparotomy within 1 hour
31 Need a laparotomy within 6 hours
32 Need a laparotomy within 1 day
33 Need a thoracotomy in ED
34 Need a thoracotomy within 1 hour
35 Need a thoracotomy within 6 hours
36 Need a thoracotomy within 1 day
37 Need theatre within 1 hour (other operation)
38 Need theatre within 6 hours (other operation)
39 Need theatre within 1 day (other operation)

CT, computed tomography; DPL, diagnostic peritoneal lavage; ED, emergency department; FAST, focused abdominal sonogram for trauma; PoP, plaster cast application.

#### Round 3

Those items that did not achieve consensus in round two were represented to all members of the group, together with a summary of the rest of the group's findings. Members were then able to change their assigned triage category after considering the opinions of the rest of the group.

Consensus was sought from group members: items reaching 80% group agreement were considered to have the consensus of the Delphi panel.

### RESULTS

Twenty nine of the 39 items from round one achieved consensus (80% or higher) after round three. The consensus items are shown in table 2.

Of the remaining 10 items, three achieved agreements of two thirds or higher (T2—need a laparotomy within six hours, need a thoracotomy within six hours; T3—need a thoracotomy within one day). All other items had a wide spread of opinions.

### DISCUSSION

Formal validation of any triage tool would ideally occur in the setting in which that tool is to be used. However, in the case of major incident tools this is not possible, for practical and

**Table 2** Specific interventions by triage category

Triage category		
T1	T2	T3
Blood within 30 minutes of arrival at ED	DPL or FAST ultrasound in ED	PoP application (long leg)
Chest drain insertion	Intravenous analgesia in ED	PoP application (forearm)
Cricothyrotomy	Femoral splint application	PoP application (long arm)
Direct pressure to control severe haemorrhage		Simple dressing application
External pelvic fixation within 1 hour		Sling application
Fluid resuscitation in excess of 20 ml/kg		Sutures
Intubation and ventilation (unless non emergent)		Need a laparotomy within 1 day
Laryngeal mask airway (unless non emergent)		Need theatre within 1 day (other operation)
Nasopharyngeal airway insertion for airway protection		
Needle cricothyrotomy		
Needle thoracocentesis		
Oropharyngeal airway insertion for airway protection		
Pericardiocentesis		
Tourniquet to control severe haemorrhage		
Need a laparotomy within 1 hour		
Need a laparotomy within 6 hours		
Need a laparotomy within 1 day		
Need a thoracotomy in ED		
Need a thoracotomy within 1 hour		
Need a thoracotomy within 6 hours		
Need a thoracotomy within 1 day		
Need theatre within 1 hour (other operation)		
Need theatre within 6 hours (other operation)		
Need theatre within 1 day (other operation)		

DPL, diagnostic peritoneal lavage; ED, emergency department; FAST, focused abdominal sonogram for trauma; PoP, plaster cast application.

ethical reasons. Expert opinion therefore has to be used; it is the basis for the ISS (although the directory upon which this is based was achieved by committee rather than a more scientifically sound arrangement), and has recently been used by both Baxt and Upenieks<sup>10</sup> and Garner *et al*<sup>11</sup> to test triage algorithms.

Current major incident triage methodologies, such as the triage sieve,<sup>1</sup> have been adapted from scores designed to triage individual patients (predominantly adults). Progress on major incident methods is hampered by the lack of a gold standard for what a major incident triage score must do. When determining the success of a triage score it is important to define what factors it is trying to discriminate. To truly determine the success of a major incident score it must be measured against what it is intended to achieve—that is, the need for clinical intervention not just injury or physiological derangement (although these will often coexist).

It is standard practice to validate these triage tools against the ISS: an ISS of 16 or higher is associated with approximately 10% mortality and has therefore been used as the cut off for defining serious injury. Triage tools are typically validated in the USA, where the ISS is used to identify those patients in need of trauma centre care.

Baxt and Upenieks<sup>10</sup> challenged the use of the ISS in validating triage tools on the basis that it is not only the severity of injury sustained that is important in determining whether a patient should be assigned a high medical priority. Clearly, if a patient has a reduced conscious level and, as a result, is unable to protect their airway adequately then they require immediate intervention: this will not be detected by ISS scoring. Similar arguments can be used for a number of outcomes and interventions that may occur.

Baxt considered the major operative and resuscitative interventions that patients often require following injury—the need for (non orthopaedic) operative intervention, aggressive fluid replacement (more than 1000 ml), and invasive central nervous system (CNS) monitoring (or a positive head computed tomogram (CT)). They also studied those patients who died from their injuries. They found that the ISS did not correlate well with the requirement for these interventions: indeed, if an ISS of 15 or higher was considered as the marker of serious injury, the ISS under correlated 20% of the time. They observed that the ISS missed a significant number of seriously injured patients, who can be identified by the intervention that they require rather than the specific injury that they sustain. Their findings are strongly suggestive that ISS is not an appropriate means by which to validate pre hospital triage algorithms, which aim to identify patients in need of urgent medical interventions.

This work was further developed by Garner *et al*<sup>11</sup> in 2001: they modified Baxt's original criteria to be more appropriate for a major incident setting. Garner compared three primary triage algorithms by their ability to predict five criteria:

- (Non orthopaedic) operative intervention within 6 hours (Baxt used 48 hours, but in a major incident setting these patients can be in a less urgent category).
- Fluid resuscitation of 1000 ml or more.
- Invasive CNS monitoring or a positive head CT scan.
- A procedure to maintain the airway, or assisted ventilation.
- Decompression of a tension pneumothorax.

Garner *et al* used these criteria to identify critically injured patients who should be triaged as priority one

(immediate) by the triage tool being tested. This thereby presents a means of determining a triage algorithm's ability to identify those patients in need of the most urgent medical intervention.

Both of these papers derived their criteria from expert opinion. Such a method is preferable to the use of the ISS as it allows for correct identification of casualties based upon medical need rather than on specific injury severities alone. This method can be applied in the validation of specific triage tools. The derivation of appropriate criteria to test against may be by committee, as is the case in the Abbreviated Injury Score (the system on which ISS scoring is based),<sup>12</sup> or by alternative means.

### Principal findings

We aimed to develop the work of Garner *et al* by determining similar clinical criteria, but through the use of a Delphi process rather than the authors' own expert opinion. The 29 consensus criteria that we have derived are not intended to be used to triage patients in a real major incident, but rather provide an alternative means by which a triage algorithm can be validated, by testing its ability to identify patients in need of such clinical interventions.

### Strengths and weaknesses of the study

We acknowledge that the criteria derived by this study are specific to the situation detailed in this article (although the general principal may be used in other situations to test other tools). This methodology may be used to derive further specific lists of criteria against which other current and future triage tools may be tested (both for paediatric and adult major incidents). The list of conditions in this Delphi is unlikely to be exclusive but may serve as a benchmark in future studies: such work is currently being undertaken by the authors. Specific intervention lists may be derived by future researchers in this area for other major incident triage tools.

The Delphi design was chosen for this study as the outcome—that is, the relative need for clinical intervention in major incidents—can only be determined by an expert group with knowledge of major incident management and clinical care. There are no more objective methods that could have been used. The strength of our approach is that we have combined opinion in a structured and anonymous way. However, the decisions made are determined entirely by the group members and these are potentially influenced by past experience or work in the field.

The experts used in this Delphi study were chosen to represent a wide range of specialities and experience in major incidents. However, it is accepted as a potential source of bias that the Delphi panel was restricted to experts in two countries only (the use of alternative experts in other locations may have produced different results). Furthermore, the experts involved were those identified as having the requisite experience by the authors: other experts may well have been available but were not contacted to partake in the study. The lack of nursing input into the study is also acknowledged: two nurses were approached to take part but declined.

The definition of consensus being achieved at 80% agreement was chosen arbitrarily before the study was undertaken. This level of agreement (13 of 16 participants) was felt to be sufficiently high to represent group agreement. However, it is accepted that higher (or indeed lower) levels of agreement could have been chosen. It is of note that only 32 statements achieved over 66% consensus; of the 29 achieving 80% agreement, six were in complete agreement and a further seven achieved 94% (15 of 16). We



believe that the use of 80% as a consensus agreement level is appropriate.

### Strengths and weaknesses in relation to other studies

There are no directly comparable studies available. However, we have followed from the work of Baxt and Upnekies<sup>10</sup> and Garner *et al*<sup>11</sup> (as described above) in using expert opinion to determine appropriate criteria.

### Meaning of the study

We have taken the approach of using an expert Delphi panel to determine specific criteria that a major incident triage algorithm should be able to discriminate into standard triage categories. These criteria may be used as an alternative to the ISS in testing major incident triage algorithms.

### Unanswered questions and possible future research

We have acknowledged that the criteria derived by this study are unlikely to be exhaustive or to apply to every major incident situation. However, they form an expert based tool against which specific major incident triage tools may be validated. Such work is being undertaken by the authors, evaluating paediatric major incident triage algorithms in a clinical setting, through a prospectively developed database of children receiving these interventions post injury. These algorithms are being validated through the comparison of ISS and the findings of this Delphi.

### CONCLUSION

We have described a novel use of an existing research tool as a means to test paediatric major incident triage algorithms. This process involved the use of an expert Delphi panel to formulate a list of interventions against which the algorithm may be tested.

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SC had the original idea for the paper. LAW undertook the study and wrote the first draft. All authors contributed to the final draft. LAW is the guarantor of the article.

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### APPENDIX

#### Background

In a major incident with multiple casualties, the medical response is heavily influenced by the rapid and accurate identification of those patients in need of immediate attention. At the same time, those whose needs can wait must also be identified to avoid overburdening the limited medical resources.

There are many triage instruments available to assist in this process, most of which have not been formally validated. In the context of paediatric casualties, the paediatric triage tape is one such triage tool. The tape relies upon physiological parameters related to height (or weight) to determine the child's triage category. This tape is currently undergoing prospective validation in South Africa.

Part of the problem with validating triage instruments lies in determining which outcomes are considered to represent serious injury. The most commonly used is the injury severity score, but this has many limitations. Some papers have used a short list of outcomes, such as death or the need for surgery within six hours, as indicators of serious injury. All methods have flaws.

I propose a different way to determine the outcomes that will be used to validate this tape: the use of an expert panel in South Africa and the UK. This Delphi study consists of 16 experts, including yourself, and I thank you for taking part.

#### Method

With hindsight, knowing the interventions performed on an individual child, it is possible to state what the preferred triage category would have been in order to treat the child within the optimum time from injury. This is, of course, in the context of multiple casualties: not every patient can be treated immediately.

When triaging patients for treatment, consideration must also be given to the amount of equipment available to you, the number of trained staff at hand, and the environment. For this exercise, please consider that there was access to just enough of everything needed to avoid the introduction of an expectant category into the triage scheme.

Please assume that triage is at the scene of the incident. Furthermore, no treatment has been undertaken before these children are triaged.

On the following pages you will find paediatric patients from a major incident. Please consider each patient in turn, and then, using this hindsight, indicate whether you believe that patient should receive *immediate*, *urgent*, or *delayed* treatment, or whether they should be triaged as *dead*.

Mark your choice in the columns next to each patient as follows:

For *immediate* treatment, tick P1

For *urgent* treatment, needing intervention within 2-4 hours, tick P2

For *delayed* treatment, needing interventions that can wait over 4 hours, tick P3

For *dead*, tick DEAD.

Please add any comments that you wish to by any of the patients.

Now read through the scenario, and then turn to the list on pages 4–7.

**Scenario**

A major incident has occurred involving children. You must triage the injured children. You need to decide

whether each child needs *immediate*, *urgent*, or *delayed* treatment, or whether, in a major incident setting, they are *dead*.

Using the hindsight of the clinical information provided, look at the following children that are injured and triage them for treatment priority.

## PREHOSPITAL CARE

## Comparison of paediatric major incident primary triage tools

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**Objectives:** To determine the sensitivity and specificity of paediatric major incident triage scores. The Paediatric Triage Tape (PTT), Careflight, Simple Triage and Rapid Treatment (START), and JumpSTART systems were tested.

**Methods:** In total, 3461 children presenting to a South African emergency department with trauma were scored using the four different methods. The sensitivity and specificity of the four scores was calculated against the Injury Severity Score (ISS), New ISS (NISS), and a modification of the Garner criteria (a measure of need for urgent clinical intervention). We also performed a Bayesian analysis of the scores against three different types of major incident.

**Results:** None of the tools showed high sensitivity and specificity. Overall, the Careflight score had the best performance in terms of sensitivity and specificity. The performance of the PTT was very similar. In contrast, the JumpSTART and START scores had very low sensitivities, which meant that they failed to identify patients with serious injury, and would have missed the majority of seriously injured casualties in the models of major incidents.

**Conclusion:** The Careflight or PTT methods of triage should be used in paediatric major incidents in preference to the jumpSTART or START methods.

Although major incidents are relatively uncommon events,<sup>1</sup> they can seriously test the responses of emergency medical services and hospitals.<sup>2</sup> All major incidents are characterised by a period of time when the casualty load exceeds the available resources. It is therefore vital that medical resources are effectively directed towards those patients who are most likely to benefit. A key step in facilitating a smooth response is effective triage, which occurs in two phases. At the scene of an incident, primary triage is a rapid "once over" to quickly identify those patients in most urgent need of medical intervention and those who can wait for further assessment. Secondary triage usually occurs at the location of the incident's main treatment centre, where time and resources allow for a more in depth triage process.

Children are commonly involved in major incidents, either as a significant proportion of the casualties or as the total patient load.<sup>3</sup> If children are involved, a number of factors influence and complicate triage decisions. Firstly, children have different physiological norms. Such differences mean that using adult scores on children will often lead to an inappropriately high triage category.<sup>4</sup> Secondly, there is often an emotional desire among rescuers to accord children, and especially young children, a higher priority. Both these factors may mean that resources will be directed away from more seriously injured adults (in a mixed adult/child incident) or that the score may fail to discriminate priorities at all (in a child only incident). In order to try to minimise these predictable problems, specific paediatric primary triage algorithms have been devised. These include: (a) the Paediatric Triage Tape (PTT),<sup>5</sup> used in the UK, and parts of Europe, India, Australia, and South Africa; (b) CareFlight,<sup>6</sup> in use in parts of Australia; (c) Simple Triage and Rapid Treatment (START),<sup>6</sup> in use in the USA for children aged older than 8 years; and (d) JumpSTART,<sup>7</sup> in use in the USA for children aged 1-8 years.

For practical and ethical reasons, primary triage algorithms are highly unlikely ever to be validated in real incidents.

Computer modelling and major incident registries may help future work in this area although there are obvious potential problems with the validity of such data. Typically, triage algorithms have been compared against the gold standard of the Injury Severity Score (ISS),<sup>8</sup> although some authors have suggested that the New ISS (NISS)<sup>9</sup> may be better.<sup>10</sup> However, the use of anatomical measures of injury such as the ISS has been questioned, as it fails to predict the requirement for medical intervention accurately.<sup>11</sup> Neither ISS nor NISS give any indication of the requirement for medical intervention at the scene of a major incident, which must surely be the most important outcome of any primary triage score. Garner *et al*<sup>12</sup> proposed the use of clinical interventions in place of ISS in the validation of adult major incident primary triage tools: the requirement for any of these interventions was taken as indicating a T1 (immediate priority) patient. These interventions are presented in table 1, and are easily modifiable to be applicable to the paediatric setting.

In this study, our aim was to determine the sensitivity and specificity of primary triage scores in the assessment of paediatric casualties.

## METHODS

We prospectively tested paediatric triage scores on paediatric attendees at the Trauma Unit of the Red Cross Children's Hospital, Cape Town. This unit sees children aged up to 12 years of age and is the major tertiary referral centre for the Cape Town area, receiving approximately 9000 injured children each year.

We prospectively collected data on all attendees meeting the following criteria: age <13 years, and presentation within 12 hours of an acute injury. Physiological, anatomical, and demographic information needed to complete the

**Abbreviations:** ISS, Injury Severity Score; NISS, New Injury Severity Score; PTT, Paediatric Triage Tape; START, Simple Triage and Rapid Treatment

**Table 1** Interventional criteria taken from Garner *et al*<sup>12</sup>, with suggested paediatric modification

Patient requires	Suggested paediatric modification
Operative intervention (non-orthopaedic; within 6 hours)	
Fluid resuscitation of 1000 ml or more, to maintain BP >89 mmHg	Fluid resuscitation in excess of 20 ml/kg
Invasive CNS monitoring, or a positive head CT scan	
A procedure to maintain the airway, or assisted ventilation	
Decompression of a tension pneumothorax	

BP, blood pressure; CNS, central nervous system; CT, computed tomography.

different scores were collected at triage using standardised printed material (for the PTT, CareFlight, and START or JumpSTART, depending on the child's age). All children were prospectively followed through to death or discharge, when the ISS and NISS scores were calculated. In addition, the case notes were examined for evidence of any of the modified Garner criteria.

### Outcome measures

We defined the performance of the scores against their ability to discriminate between T1 (immediate priority) and not-T1 (urgent or delayed priority). For comparison against ISS, children were considered to be seriously injured (and therefore rated as T1) if they had a total ISS >15. Children with an ISS ≤15 were considered to be not-T1. The same cutoff was applied against the NISS. For analysis against the modified Garner criteria, the requirement for one or more of these interventions was considered an indicator that the child was T1.

The sensitivity and specificity of the PTT, Careflight, and START/JumpSTART were calculated individually against ISS, NISS and modified Garner criteria. Sensitivity reflects the proportions of those patients who are T1 who are correctly identified as T1, while specificity is the proportion of patients who are not-T1 who are correctly identified as not-T1.

To determine how the scores would perform in practice, we calculated the ability of the score to perform in three different types of major incident with varying proportions of seriously injured casualties. The principle outcome was the proportion of children correctly identified as truly T1 and truly not-T1 against falsely T1 and falsely not-T1 (that is, the accuracy of the score for each scenario). The characteristics of the hypothetical incidents were as shown below:

- Incident 1: 100 paediatric casualties, 10% T1
- Incident 2: 100 paediatric casualties, 30% T1
- Incident 3: 100 paediatric casualties, 60% T1.

The results against the hypothetical incidents were rounded to the nearest whole number. The flowcharts for each triage methodology are available online (<http://www.emjonline.com/supplemental>).

### RESULTS

In the study period, 5508 children presented to the trauma unit within 12 hours of injury. Of these, 3597 children met the entry criteria for the study, and 3461 (96%) children were enrolled. The study population was 63% male, with a median age of 7 years. JumpSTART was used to triage 2441 children (aged 1–8 years); the remaining 1020 were triaged by START methodology in accordance with the algorithms' instructions.

Of the 3461 patients in this study, 1983 (57.3%) presented within 1 hour of injury, 2476 (61.5%) within 2 hours, and 2910 (84%) within 4 hours. There were 46 patients (1.3%) with penetrating trauma.

There were 188 children (5.4%) with an ISS of >15 and 314 (9.1%) with an NISS >15, and 312 modified Garner criteria were present in 200 (5.8%) children. For each of these three standards, the sensitivity and specificity rates for the different triage algorithms are presented in table 2.

Table 3 shows how each score performs in each type of hypothetical incident with differing proportions of seriously injured casualties. The score with the best performance in each incident is marked in bold. The JumpSTART and START methods were analysed independently and also as a 50:50 split, as they are components of the same triage system, only divided as to which age they should be applied.

### DISCUSSION

#### Principal findings

We found that there are significant differences in the performance of the triage scores when analysed against a pool of patients presenting to an emergency department. Analysis of the sensitivity and specificity figures suggests that the performance of the PTT and CareFlight scores is similar, and both are better than the JumpSTART and START scores. The JumpSTART and START scores have worryingly low sensitivities when measured against anatomical injuries, resulting in identification of very few patients with serious injury; in other words, they miss the majority of serious anatomical injuries.

It is our belief that the Garner criteria are probably a better measure of score performance than the anatomical descriptors of injury. In this regard, overall performance of the CareFlight and PTT scores is better than the JumpSTART/START methodologies in all but the most severe incidents. Overall, the CareFlight score appears to be the best performing, although the difference between it and the PTT is probably clinically insignificant.

#### Strengths and weaknesses of the study

Our study uniquely applied a range of scores simultaneously to the same group of paediatric patients presenting with trauma. This allowed us to determine the performance of each score against interventional and anatomical criteria, and to draw direct comparisons between the scores. Our analysis against hypothetical major incidents shows how a score might actually help triage officers in the field with their triage decisions. In essence, it informs us of how well the score might discriminate between those who need immediate care and those who do not.

Our study does have some weaknesses. The regular recording of the triage score criteria over a period of months may have led to a much greater degree of familiarity with the methods than could be expected in a real incident. Our results probably therefore demonstrate the best performance that the scores could hope to achieve. While this study was designed to prospectively assess the usefulness of the primary triage algorithms, the numbers of patients classified as T1 by ISS (or NISS/modified Garner criteria) is relatively small. However, as the majority of patients from a major incident setting are likely to be minor in nature,<sup>1</sup> the patient distribution in this study is therefore representative.

We had to modify the Garner criteria to a paediatric population but believe that the changes made are intuitive and reflect current paediatric resuscitation.<sup>11</sup>

Comparing developed world algorithms in a developing country may lead to bias in the conclusions, as the physiological parameters used by the tool may be different in that country. However, work undertaken by one of the

**Table 2** Comparative analysis of MI primary triage algorithms: results by ISS, NISS, and presence of one or more modified Garner criteria

	ISS > 15		NISS > 15		Garner	
	%	95% CI	%	95% CI	%	95% CI
PTT						
Sensitivity	37.8	32.7 to 42.5	26.1	23 to 28.8	41.5	36.8 to 45.6
Specificity	98.6	98.3 to 98.8	98.9	98.5 to 99.1	98.9	98.6 to 99.2
CareFlight						
Sensitivity	48.4	43.4 to 52.8	31.5	28.5 to 34.1	46	41.2 to 50.2
Specificity	98.8	98.6 to 99.1	99	98.7 to 99.3	98.9	98.6 to 99.1
JumpSTART*						
Sensitivity	3.2	1.3 to 7.5	2.4	1 to 5	0.8	0.1 to 4.1
Specificity	97.8	97.7 to 98	97.8	97.6 to 98	97.7	97.6 to 97.8
START†						
Sensitivity	31.3	21.5 to 42.8	22.3	15.6 to 30.7	39.2	29.3 to 50
Specificity	77.9	77.3 to 78.7	77.3	76.6 to 78.3	78.7	77.9 to 79.5

\*JumpSTART, n = 2441; †START, n = 1020.

authors<sup>14</sup> shows that the heart rate and respiratory rate of children in the UK and South Africa may be considered the same by age. Hence, direct extrapolation of the results to USA or UK populations should be possible. It should also be remembered that we tested tools in a hospital setting, not in the prehospital environment where they would be used.

#### Strengths and weaknesses in relation to other studies

Many experts still consider that the ISS is the only appropriate means against which to validate triage algorithms: it has been studied extensively as a summary measure against which day to day triage tools are tested. An ISS of  $\geq 16$  is widely regarded as indicating serious injury, and this cutoff point is used to direct patients to trauma centre care in regionalised systems such as that in the USA.<sup>15,16</sup> The use of NISS has been suggested to be a more accurate indicator of severity of injury,<sup>10</sup> although it has still to gain wide acceptance.

However, the ISS (and NISS) were not designed to serve as markers of resource requirement, and there is good evidence that the ISS fails to correlate with this measure.<sup>11</sup> The NISS is likely to suffer from the same limitation, although it has not been studied in this regard. In primary triage at a major incident, severity of injury is of little relevance; rather, triage is aimed at prioritising the requirement for medical

intervention. A patient with a minor head injury but an obstructed airway due to his position is of higher priority than a patient whose airway is intact, regardless of the severity of injury.

The use of clinical interventions given Garner *et al*<sup>12</sup> as a marker of urgency of requirement for intervention helps to overcome the limitations of the ISS and NISS. Although they chose a limited range of interventions on which to base their analysis, their work is important in opening up this field for future research. The requirement for any of the clinical interventions that they proposed (modified slightly for children to reflect different fluid resuscitation strategies) may be used as a marker to indicate a patient who should be triaged as T1 by any triage algorithm. Although their work allows research in this field to begin to move away from the use of inappropriate scoring systems, the interventions proposed by Garner *et al* can still only be used to distinguish between those patients who are T1 (immediate) and those who are not. As with the use of ISS and NISS, further analysis of the ability of triage algorithms to identify T2 (urgent) and T3 (delayed) patients is impossible. Development of the use of clinical interventions as markers of T2 and T3 patients should be possible, and we are currently undertaking work in this regard.

#### Implications of the study

Either the Careflight or PTT should be adopted as the method of choice for the initial pre-hospital triage of paediatric patients in major incidents. Policymakers should decide which method to use, based on current knowledge, exposure, and the practicalities of each method for field use. We have not compared the practicalities or ease of use in this study. However, our experience suggests that there is little difference in terms of time to perform or training.

#### Unanswered questions and future research

Our study was unable to discriminate between T2 and T3 casualties, which is arguably as important as discriminating T1 casualties at the scene of an incident. In order to do this, additional criteria, such as the Garner criteria but with T2 and T3 outcomes, must be available. We are currently conducting a study to define exactly those criteria.

#### CONCLUSION

We have presented a comparison of the most commonly used major incident paediatric primary triage algorithms, and found that none of the tools have good sensitivity (the ability to identify seriously injured children), but all have excellent specificity (the ability to identify less seriously injured children). A more accurately designed triage algorithm is

**Table 3** Accuracy scores for each triage method in three hypothetical incidents.

	Gold standard (%)		
	ISS	NISS	MGC
10% T1 casualties			
PTT	93	73	90
Careflight	<b>94</b>	<b>92</b>	<b>94</b>
JS	88	88	88
START	73	72	75
50:50 JS:START	81		82
30% T1 casualties			
PTT	80	77	81
Careflight	<b>84</b>	<b>78</b>	<b>83</b>
JS	69	69	92
START	64	61	67
50:50 JS:START	67	65	80
60% T1 casualties			
PTT	63	56	65
Careflight	<b>69</b>	<b>59</b>	<b>68</b>
JS	41	40	87
START	50	44	55
50:50 JS:START	46	42	71

The score with the best performance for each incident is in bold type. MGC, Modified Garner criteria; JS, JumpSTART

required. In the meantime, the use of START and JumpSTART for children cannot be recommended.



Supplemental data can be found online at <http://www.emjonline.com/supplemental>.

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