

Chapter 1.

1.1 Introduction

The idea for this study was conceived whilst working abroad in the aftermath of the Pakistan earthquake in November 2003. It was essential to determine whether children presenting to the remote field hospital situated in the foothills of Kashmir had fractures or not. However, no X-ray facilities were available and the medical team had to rely purely on their clinical acumen to determine the fracture diagnosis rather than definitive diagnostic X-rays. The idea that there may be an alternative diagnostic tool to detect fractures was conceptualised and developed.

Is there an alternative to X-rays in the diagnosis of fractures? Could thermal imaging equipment be used to determine fracture diagnosis? If thermal imaging could be used as an alternative to X-rays, what were the challenges surrounding its use? If thermal imaging was proven to be a diagnostic alternative to X-rays then the practicalities surrounding the diagnosis of fractures in the remote setting could be resolved with a simple, inexpensive and transportable solution. A single case study carried out by Cook & Thakore (2005, p. 395-397) examined the use of thermal imaging for the detection of a child's fractured distal radius with good effect, demonstrating a higher heat signature from the injured arm when compared with the uninjured arm. They suggested that the inflammatory response initiated when a child fractures their wrist could be measured and used to accurately detect a fracture without the need for an X-ray. This study has been

developed to determine whether it is feasible to use thermal imaging as a diagnostic test to detect wrist fractures in children.

The examination and detection of fractures in children can be complex and the reasons for this are two-fold; firstly, owing to the nature of children's bone development, because they are more cartilaginous and thus often can be subtler to detect. Secondly, children may be unable to give a good history of events leading to the incident causing the injury and, in addition, may find it hard to explain their specific symptoms. Thus, in their observational study of 106 children, Webster, Goodacre, Walker, & Burke (2006, p. 354) suggest that neither clinical examination nor history alone can determine the presence of a fracture in the majority of children. Injury localisation can be difficult to assess in young children because of their inability to pin point the exact injury site and the lack of clinical signs, such as swelling, bruising and loss in function. An observational study carried out by Webster et al. found that although clinical features of a fracture were present in the majority of children, these features were unhelpful in diagnosing the presence of a fracture or reducing the amount of radiographic investigation as they had a high sensitivity when the clinical features were present but a low specificity, meaning that fractures could not be ruled out by using clinical features alone (Webster, Goodacre, Walker, & Burke 2006, p. 354).

Webster et al. suggest that there is an over use of X-rays in children, however there is currently no other clinically acceptable gold standard for detecting fractures in children (2006, p. 354). This complexity can lead to an overuse of X-ray examination and a misdiagnosis of the injury incurred. Hallas & Ellingsen (2006, p. 4), in a study conducted over two years, investigated 5879 patients

who visited the Emergency Department (ED) with injuries. They found that 1% of all visits to the ED resulted in an error in fracture diagnosis, with 3.1% of all fractures not diagnosed at the initial visit to the ED. This error rate is increased in young children because of the subtlety of the fracture and the minimal disruption to the cortex of the bone.

A study carried out by Brunswick, Likahainmpour, Seaberg, & Mc Gill (2008, p. 346) found that this error rate was up to 10.6% of all X-rays interpreted on children, with 5.7% of the X-rays being over-read and 3.13% of fractures being missed due to misreading of the initial X-ray. Brunswick et al. concluded that although X-rays were considered to be the gold standard for the diagnosis of fractures, sensitivity of X-ray interpretation was at 96.8%, thus a margin of error is inevitable. Suggesting that although x-rays are considered to be the gold standard for detecting fractures in children they are not 100% accurate and they are heavily dependent on the level of experience of the clinician interpreting them. This pilot study tests the hypothesis that thermal imaging can be used safely and effectively to detect wrist fractures in children.

This thesis presents the findings of a pilot study using a quasi-experimental design, conducted to evaluate whether thermal imaging can be used as a diagnostic tool to detect wrist fracture in children under the age of 16 years of age. The thesis consists of seven of seven chapters. The first chapter will introduce the background of the study, the theories behind thermal imaging and its use in medical science, along with the aims and objectives of the study.

Chapter two will identify the literature surrounding the use of thermal imaging to detect fractures in children, analyse and critique the wider research that has informed the research methodology and design, including alternative methods used to detect fractures in children other than the gold standard of X-rays. Chapter three will describe the methodology and research design used for this study, providing details of the rationale used for the trial design. Chapter four will describe the data from the study and display the results using tables and descriptive terms. The fifth chapter will discuss the findings of the study, including the limitations that have been identified and the implications for future practice. The final chapter will be a reflective account of the overall doctorate experience and its implications for my practice.

1.1.1. Background of medical thermal imaging

The earliest documented attempt to measure fever in humans is by Galen AD 170 (Ring, 2004p 800) who was convinced that fever was part of a systemic illness. Since then scientists and medical researchers have strived to unlock the value in human temperature measurement both for human thermo/regulation and its value in establishing diagnosis. For centuries clinicians have had to rely on thermometers as their only source of accurate temperature measurement (Mackowaik, Wassermann et al 1992). Modern digital infrared cameras are capable of sensing changes in temperature at 0.8°C or better which has transformed their accuracy and ability to detect systemic illness and injury (Ring & Ammer 2012). The first paper into the medical application of thermography was conducted by Lawson (1956), examining whether thermal imaging could be used in the early preclinical diagnosis of breast cancer in 1956 (Lawson, 1956). Since then thermal imaging has been used to study

the flow of blood, the detection of breast cancer, and muscular performance of the human body and many other medical applications (Ring & Ammer 2012 p 35). The advantages of thermal imaging, is that it is a non-invasive tool, which maps the surface temperature of a body or an object, with no evident after-effects or sequelae (Bagavathiappan, et al, 2009 p 12). Over the last 50 years thermal imaging has undergone constant development and has been developed into a powerful diagnostic tool in which to study thermoregulation in the human body (Ring, 2003,p 8). Thermographic imaging is defined as the detection of radiation within the infrared ranges of the electromagnetic spectrum (900-14,000 nanometres or 0.9 - 14 μ m). It produces images of that radiation called thermograms (Bowley, 1999). The potential advantages of thermal imaging are that they provide clinicians with an accurate, non-invasive, inexpensive portable form of diagnostics not readily found in modern diagnostics equipment today (Arora et al 2008, p 523).

1.1.2 The relationship of thermal imaging and human physiology.

Temperature distribution on the surface of the human body is determined by the temperature of the internal organs, the conduction of heat from muscle and adipose tissue and the heat emissivity of the skin. Therefore, the temperature measured on the skin may be indicative of the temperature of an internal organ and the heat properties of the tissues separating the organs from the skin. The heat projection from these organs and internal structures is carried out by three essential processes: conduction, radiation and convection. The intensity of the heat produced by an organ is dependent on the intensity of the organ's metabolism and processes of heat transport by fluids, mainly blood (Mabuchi, K., Genno, H., Matsumoto, K., Chinzie, T.,

& Fujimasa, I., 1995, p. 122).

The human body has a very advanced system of thermoregulation and is very stable when compared to animal subjects. Humans have mechanisms by which to cool down or warm up the body using internal controls i.e. shivering when cold, vasodilatation and sweating when hot. However, skin temperature could vary up to 10°C when compared with internal organs depending on the environment and the external temperature of the surroundings in which the skin is exposed (Romanovsky 2007, p. 296). Organs can individually display different temperatures depending on their methods of conductivity and metabolism. For example, the temperature of blood itself is not a constant and depends greatly on local vasomotor changes and control (Jung & Zuber, 1998, p. 16).

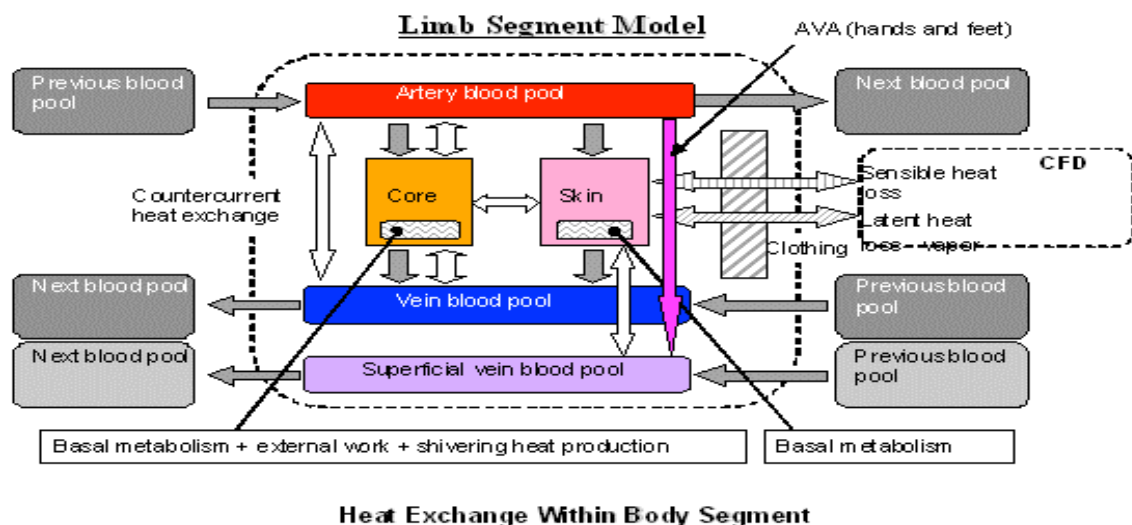


Figure 1 Limb segment Model. Adapted from ASME. Retrieved 2014, from <http://images.asme.org/MEMagazine/PaperLibrary/18211.gif>

When measuring skin or surface temperature of the human body, caution must be applied to the results as the skin temperature can often differ dependent on

thickness the skin surface, adipose layers and the internal transport system supplying the area. Muscle and adipose tissue can often act as a resistor and thus scatter the heat flux, which can be mistakenly observed on the thermal image as a decrease in temperature (Jung & Zuber, 1986, p. 22). The mean temperature of the skin surface under normal-thermic conditions is between 33.5 and 34° C.

When designing a study examining heat differences in the body to determine differing pathology, the normal range of skin temperature must be taken into account to ensure reliability and reproducibility can be maintained within the experiment. Jung and Zuber (1998, p.15) suggest that any pathological process, either inflammation or tumours, can cause change in this heat flux generated by a given tissue. Jung & Zuber (1998, p. 15), Ring & Ammer (2000, p. 11) and Ring, Jones, Ammer & Plassmann (2004, pp. 93-98) have all carried out studies that suggest that pathological changes can result in a skin surface temperature increase of up to 0.5° C higher than the surrounding tissue. Thus 'any temperature difference higher than 0.5° C can be considered as a sign of a pathological process' (Jung & Zuber, 1998, p. 15). They conclude by stating that normally this temperature measurement is much higher, quoting a range between .01 to 1.0° C dependent of the methods used and the accuracy of the measuring device. Thermographic studies are designed to estimate these changes in temperature and thus, in theory, can detect the physiological changes present.

1.2. Introduction to the study

This pilot study has been designed to test the feasibility of using thermal imaging as a diagnostic test, to detect wrist fractures in children (Leon, Davis & Kraemer, 2011, p. 626). (Definition from the medical research council suggesting that they are synonymous)

The definition of a pilot study is:

‘An investigation designed to test the feasibility of methods and procedures used for a later larger scale study. A pilot study is synonymous with a feasibility study intended to guide the planning of a large-scale investigation (Thiabane et al. 2010, p. 1471; Lancaster, Dodd, & Williamson, 2004, p. 308).’

The objectives of a pilot study have been detailed by the British Medical Research Council, which explicitly recommend that all phase III studies should be preceded by a pilot study which tests the processes of development, feasibility, evaluation and implementation of a study prior to its commencement (Craig, Dieppe, Macintyre, Michie, Nazareth, & Petticrew, 2008, p. 337).

1.2.1 The objective of a pilot study is to:

- Trial a new procedure intended for use in a larger programme of research.
- Establish power calculations required for a full-scale study.
- Establish how many patients and/or healthcare professionals can be recruited.
- Evaluate the financial, technical, administrative feasibility of the study.

- Test the feasibility of a full-scale study, including issues of data collection, protocol adherence, and research question design.

(Craig et al., 2008, p. 338)

This study has been designed to adhere to the above recommendations and will test the concept of whether thermal imaging can be used to detect the physiological changes that take place when a child fractures their wrist by detecting the inflammatory response and measuring the heat associated with this response. The study was designed to determine the feasibility of recruitment, randomisation, intervention, implementation, blind assessment criteria and retention in order to carry out a larger scale phase III clinical trial, as required by the Medical Research Council (Leon, Davis, & Kraemer, 2010, p. 628; Craig et al., 2008, p. 337; Thiabane et al., 2010, p. 1473).

The hypothesis that thermal imaging can be used to detect fractures in a child's forearm has not been tested in an experimental/quasi-experimental environment before, therefore a pilot study was required to test the feasibility of the hypothesis posed. The study used a thermal imaging camera to take thermal images of the injured and uninjured arms of children presenting to a busy Emergency Department over a one-month period. The thermal images were taken at the same time as the X-rays to ensure no delay in treatment or double movement of the affected limb. Theoretically, given the exothermic reaction that takes place when a child fractures their arm, the thermal image should detect a temperature rise in the affected arm. Thermal imaging may therefore be useful to determine whether an intense inflammatory process occurs, as would be seen at a fracture site. The hypothesised benefits in using thermal imaging rather than

just X-raying any child that meets the requirement for X-ray are associated with ease of use, accessibility of equipment and reducing the child's exposure to X-rays. However, the risk to this research is that the exothermic reaction that takes place in a soft tissue injury may mimic that of a fracture, thus proving the null hypotheses that thermal imaging cannot be relied upon clinically to detect fractures in children's wrists.

The use of thermal imaging within the hospital environment has been shown to be beneficial in many areas of health care science, especially in the diagnosis of Reynaud's syndrome and burns (Ring & Ammer, 2000, p. 8), however studies for its use have never been conducted within the emergency setting. This research will add to the body of knowledge surrounding the practical applications of thermography in health care practice.

1.2.2 Aim of the study

The aim of this pilot study is to examine whether a full phase III study would be beneficial in determining whether thermal imaging can be used as a diagnostic tool to detect fractures in children who attend the emergency department with an injury to their wrist when compared with the gold standard of X-rays.

1.2.3 Definition of a diagnostic test

Throughout this thesis the term diagnostic test or diagnostic tool is used to describe the research conducted, the definition of a diagnostic test is as follows:

“A diagnostic test is a procedure performed to confirm, or determine the presence of disease in an individual suspected of having the disease,

usually following the report of symptoms, or based on the results of other medical tests”(Whiting et al., 2011, p. 529).

This study will explore whether thermal imaging can be used as a diagnostic test to detect fractures in children, using X-rays as the gold standard comparator.

1.2.3 Objectives of the study

Thabane et al. (2010, p. 1471) suggest that pilot studies should have primary and secondary objectives established. The primary objectives should relate to the research topic being examined and the secondary objectives should relate to the research methodology and process. The primary objectives have been adapted using Sackett & Hayes’ (2002, p. 20) structured approach to determine the value of a diagnostic test with regards to diagnostic research. Sackett & Haynes suggest that, in order to determine whether a diagnostic test is of value, four questions need to be answered (2002, p. 20).

1.2.3.1 Primary objectives for this study:

1. To determine whether thermal imaging (thermography) can be used to detect fractures in children’s wrists.
2. To examine whether patients with a 1°C or greater difference in temperature on thermal imaging results are more likely to have a fracture of their wrist.
3. To determine in patients who it is clinically sensible to suspect a fracture, does the level of the test result distinguish those with or without a fracture?

1.2.3.2 Secondary objectives for this study:

- To test the feasibility of a full-scale study, including the process surrounding data collection, methodology, protocol adherence and research question design.

1.3 Physiology behind the inflammatory response to bone healing

An injury that fractures bone not only damages the cells, blood vessels and the bone matrix but also the surrounding soft tissue including muscles and nerves. Immediately following the injury an inflammatory response is elicited, which peaks around 48 hours and then disappears almost completely by one-week post fracture (Dandy & Edwards, 1999, p. 36). In children, this response is more rapid due to the vascular nature of their bones when compared with adults. The fracture site in children generally occurs where cartilaginous bone meets newly calcified bone, thus producing a quicker inflammatory response resulting in a rapid inflammatory response and clot formation (Lovell & Morrissy, 2006, p 1435).

Damage to bone and its vascular endothelium results in the activation of the complement cascade, platelet aggregation and the release of its α -granule response. This platelet deregulation releases growth hormone factors and triggers chemical signals. The conductors which induce the clotting cascades are platelets, which have the duty of homeostasis and mediator signalling through the elaboration of chemottractant growth factors, polymorphonuclear leukocytes, lymphocytes, blood monocytes and macrophages are attracted to the wound site and are activated to release cytokines that stimulate angiogenesis (Jacobsen, 1997, p. 87; Lindaman, 2001, p. 99). The extravasated blood collection will then clot. Hematoma accumulates within the medullary canal between the fractures ends and beneath elevated periosteum and muscle (Jacobsen, 1997). The formation of the clot serves as a haemostasis and thus limits further haemorrhage as well as becoming a fibrin network that provides the pathway for

cellular migration (Sfeir, Ho, Doll, Azari, & Hollinger, 2005, p.23). This inflammatory response creates a heat flux which, through conduction is transferred to the overlying skin and therefore can be detected by a thermal imaging camera (Hosie, Wardrope, Crosby, & Ferguson, 1987, p. 117).

1.4 Types of fractures

This study will concentrate on the diagnosis of fractures in the distal radius and ulna of a child's wrist. The classification of fractures seen in children's wrists are illustrated below. Buckle and torus fractures are the most common fractures seen in young children due to the cartilaginous nature of children's bones (Lovell & Morrissy, 2006, p. 1435). The X-ray shown below is of a buckle fracture in a four year old child's radius.

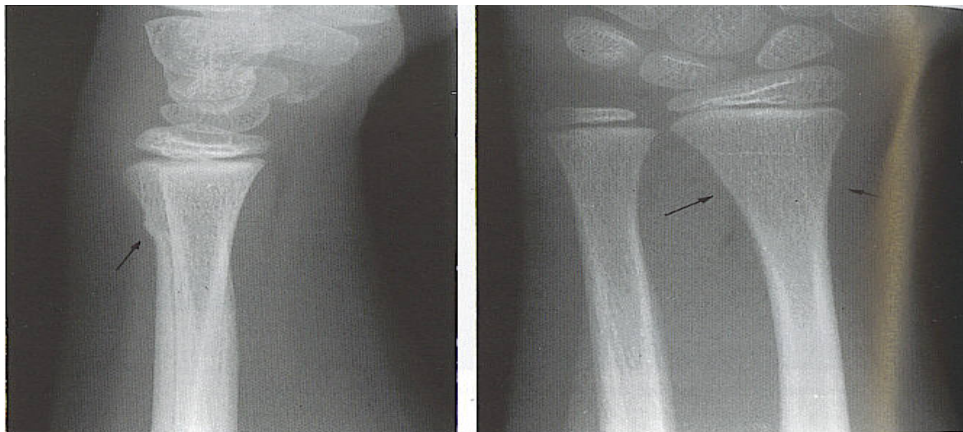


Figure 2: X-ray of a child's wrist demonstrating a buckle fracture to their distal radius.

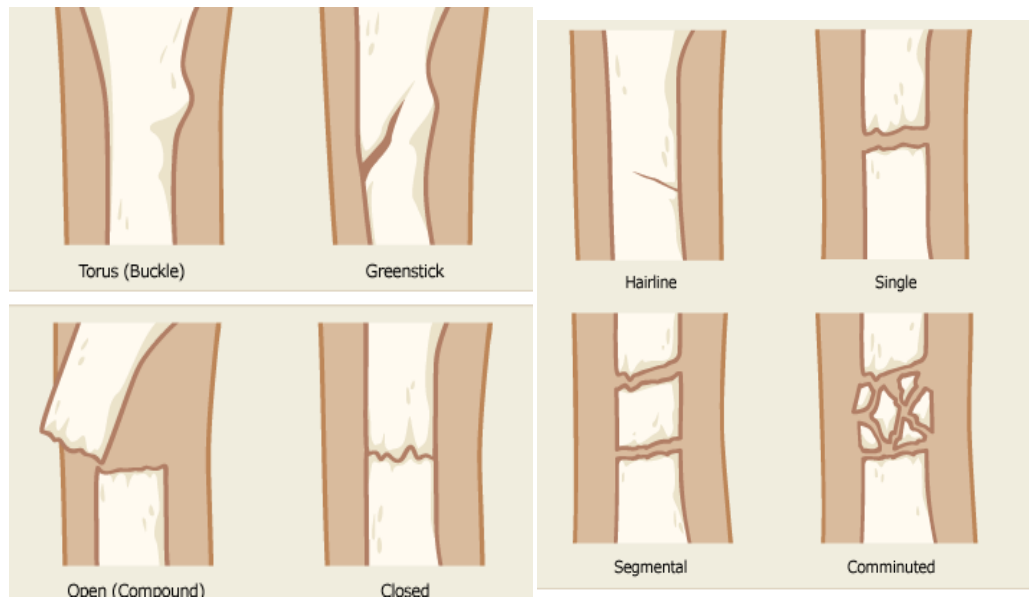


Figure 3: Classifications of fractures. Adapted from Medical Addicts. Retrieved 2014, from <http://medaddicts.blogspot.co.uk/2012/12>

Due to the cartilaginous nature of young children's bones, the bone is more likely to bend rather than break, one side of the bone bends causing the bone to buckle without breaking the cortex on the other side. A green stick fracture is a partial break in cortex of the bone associated with a bend or bowing of the other cortex. As children get older and the bone becomes more mature, the fractures seen become more "complete" resulting in fractures through both cortex's of the bone, as illustrated above. These can become more complicated in their nature either by being fragmented (compound) or displaced. These fractures can become more complex when they extend into the child's growth plates, called Salter Harris fractures (Lovell & Morrissy, 2006). This study will attempt to use thermal imaging to discover whether a different approach could be used to detect fractures in children, by detecting differences in the surface temperature of the injured wrist compared with the uninjured wrist.

1.4 Summary

This thesis will explain the research design and methodology used to examine whether thermal imaging can be used to diagnose fractures in children, whilst also explaining and examining the results gained over a one-month period researching children in an emergency department. A literature review was carried out to evaluate the evidence surrounding the use of thermal imaging within this specific field of practice to date. The evidence for the use of thermal imaging in medical diagnostics is growing exponentially. This thesis will determine whether the study of thermography in the diagnosis of children's fractures is a study worth pursuing. It may also determine whether thermography could be used as the new non-invasive form of imaging in children with suspected fractures.

Chapter 2

Chapter 2: Systematic review of Literature

The aim of this chapter is to analyse and critique current literature regarding the use of thermal imaging, for the detection of fractures in children. Exploring the concept and themes surrounding this study. Much of the literature within an application and historical context have been discussed in the previous chapter, however very little research has been conducted in regard to the detection of fractures using thermography as a diagnostic tool. The researcher carried out a systematic search of the literature between 2009 and 2014 in order to review the evidence for using alternative methods of diagnostic tools to detect fractures in children.

The objectives for this review are to focus on an overview of thermal imaging and its evolution within medical science. It will analyse the use of thermal imaging in the context of the detection of fractures and its use in paediatric medicine. The review will examine the camera systems used and how they were set up, examining which measures were applied to ensure reliability and reproducibility of results. This review will also analyse the comparison and outcomes measured used focusing on the methodology and study design, paying particular attention to the results and how they were obtained and reported. This review will also investigate and analyse the use of alternative methods of fracture detection compared with x-rays. The focus of this review is to examine all of the relevant previous studies conducted to inform the methodology and research design used to develop this pilot study.

2.1 Search strategies

A literature search was performed in the medical databases Ovid, British Nursing

Index CINAHL, EMBASE, International Bibliography of Social Sciences, INSPEC, Mantis, MEDLINE and the International Thermology Literature Database held at the University of Mid Glamorgan.

The following key words were used for the review:

- Thermography, thermology, thermal imaging;
- Temperature measurement, skin temperature, core temperature;
- Thermal imaging in orthopaedics', rheumatology, children, emergency care, fracture management;
- Methodology in thermal imaging research;
- Quasi-experimental design or observational study.

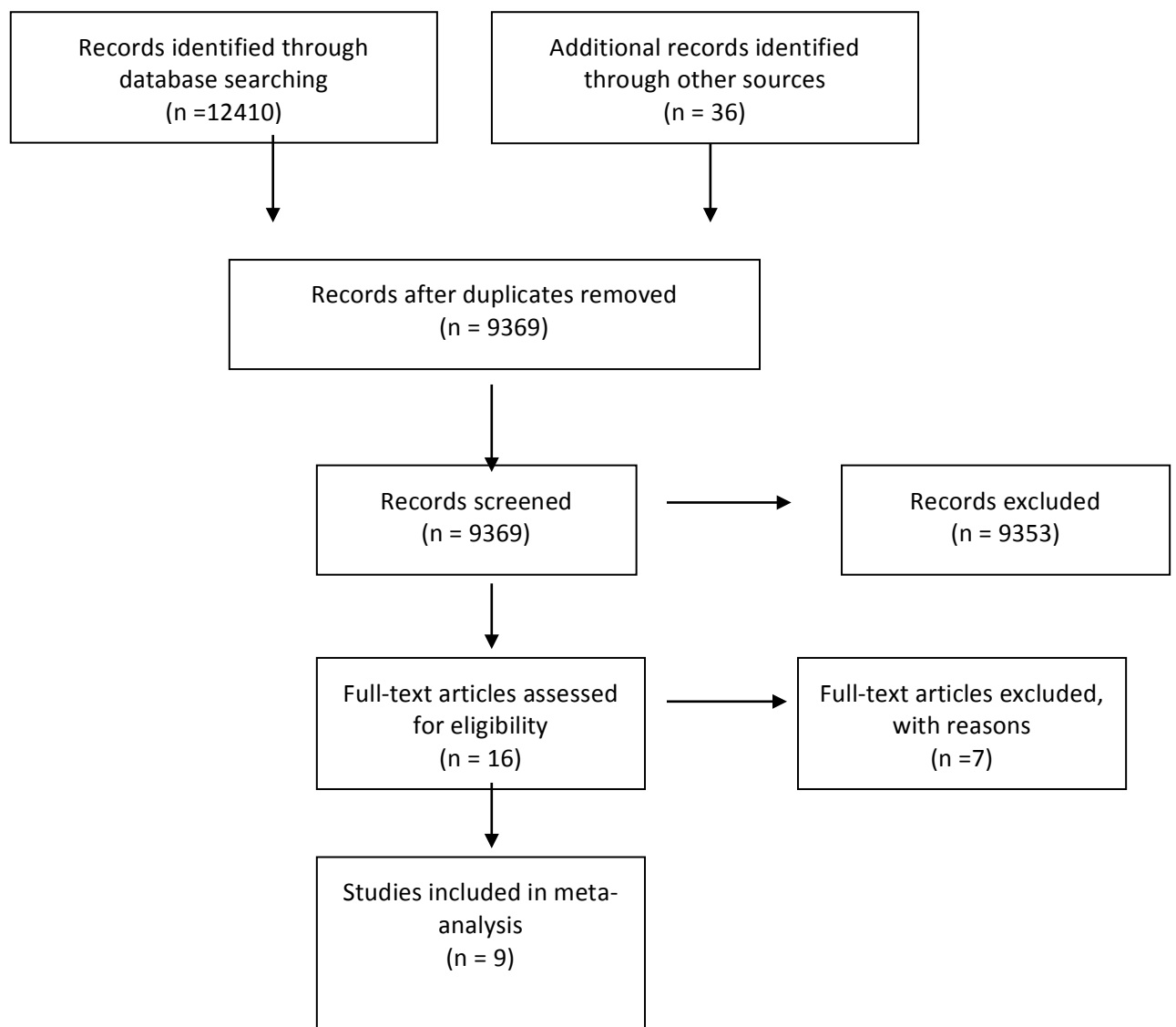
This list of criteria was devised using Professor Ammer's guidance on literature reviews for thermal imaging (Ammer, 2006, p. 16). The search yielded 12,456 publications. After removal of duplications 9369 remained, 4.6 % of these were not written in English with the main other languages being Japanese or Russian. From this review and following on from Professor Ammer's annual review there is little doubt that research into the speciality of thermal imaging in medicine is becoming a more popular area of study, the continent of Europe remaining the epicentre of temperature research when compared to that of America and the rest of the world.

The literature reviewed highlighted 14 areas of specific interest, which could be aligned to this research study as they all concentrate on the ability of thermal imaging to detect temperature changes from patho-physiological alteration within the human body, either from internal structures such as organs or those from muscle, ligaments and bone. This literature review will examine the papers and

research studies pertaining to these areas in order to assist with the development of the research question, subsequent design and methodology. Most of the studies were carried out in adult patients concentrating mainly on physiological applications of thermology, specifically breast screening for breast cancer (N= 1670). Ninety-seven studies related to the use of thermal imaging in children; however, these focused almost exclusively on the use and the development of tympanic thermometry and its accuracy. One particular study did highlight the use of thermology for detecting blocked ventriculoperitoneal shunts in children with remarkable accuracy. Although not relevant to this paper further research in this area could be important in the practice of emergency medicine. Three papers focused on the ability of thermal imaging to measure the depth of burn in children, these papers were rejected from this review but may be extremely useful for informing burn care in the future.

A number of papers related to orthopaedic conditions of which 65 related to fracture detection (See Table 2.1). The researcher reviewed all of the 65 papers highlighted in the search using *End Note x3* as a data storage facility. A review of all the abstracts resulted in 9353 papers being rejected because they were either published in a different language or had no relevance to the subject matter within this study. One of the major concerns regarding a systematic review of the literature and meta analysis is that a great number of the studies conducted on a specific subject, especially those with negative results are not published or hidden in university research libraries, (Egger, Davey Smith, Altman, 2001). To endeavour to negate this concern the researcher visited the thermal imaging library of the University of Glamorgan and the British library in London, however there is no complete way of ensuring that no study was missed.

Figure 4: Flow diagram of the literature review process



(Moher Liberati , Tetzlaff , Altman, 2009 p 332)

2.2 Thermal imaging for the detection of fractures

The literature search found no study involving the detection of fractures in children's wrists using thermal imaging as a diagnostic tool. However, 16 papers concerned with the detection of injury were highlighted in the review for a full text review. These papers were reviewed in depth. Six papers were rejected either because they were written in a foreign language or that they did not focus on

fracture diagnosis specifically.

Table 2.1: Discounted papers

Authors	Title	Rejected
Lobenko, (1983)	Use of liquid-crystal thermography for the diagnosis of injuries to the extremities]	Article in Russian
Ell, P. J. (1975)	The clinical role of skeletal scanning	Review article, not focussing on fractures
Hsieh, J. C. (1990)	Clinical application of infrared thermography in diagnosis and therapeutic assessment of vascular ischemic pain	Case study, no fracture diagnosis
Batjay, & Gyrou (1988)	Telethermovisions- Untersuchungen beim Morbus Perthes	No focus on fractures
Dol'nitskii, O. V. Lazaretnik, BSh, Danilov, A. A. 1983	Determination of the thermotopography of the hand using a thermograph and liquid crystals in children with injuries of the median and ulnar nerves	No focus on fracture diagnosis
Siegel, M. G. Siqueland, K. A. Noyes, F. R. 1987	The use of computerized thermography in the evaluation of non traumatic anterior knee pain	No fracture diagnosis
Merkulov, V. N. Dorokhin, A. I. Sokolov, O. G. Mininkov, D. 2008	Diagnosis and treatment of tubular bone fractures complicated by defective consolidation of bone fragments in children and adolescents	Article in Russian only abstract available

The 9 remaining papers were reviewed using methodological quality criteria for carrying out a systematic review described by Mant (2005), which is closely linked to the Standards for Reporting of Diagnostic Accuracy (STARD) checklist (Bossuyt, 2003) for reporting diagnostic accuracy. The rationale for choosing the STARD (Bossuyt, 2003) checklist over the Consort checklist (Moher, Hopewell, Schulz, Altman, 2010p 869), was that not all of the papers reviewed were

randomised control trials and therefore the Consort standards would not automatically apply (Consort, 2010).

The assessment criteria used for these papers were:

1. Was the reference standard appropriate?
2. Were the reference standard and the diagnostic test interpreted independently of each other?
3. Was the reference standard applied to all patients?
4. Was the test evaluated on the right sort of patients?
5. Is it clear how the test was carried out?
6. Is the test reproducible?

Table 2.2: Methodology for assessing diagnostic accuracy of test

Paper	1	2	3	Relevant patients and numbers treated	5	6
Devereaux, et al. (1984)	Yes	Yes	Yes	Yes N=. 18	Yes	Yes
DiBenedetto, et al. (2002)	Yes	Yes	Yes	Yes N=30	Yes	Yes
Gradl, et al. (2003)	Yes	Yes	Yes	Yes N=158	Yes	No
Hosie, et al. (1987)	No	Yes	Yes	Yes N=. 50	Yes	Yes
Niehof, Beerthuisen et al. (2008)	Yes	Yes	Yes	Yes N=. 120	Yes	Yes
Posinkovic and Pavlovic (1989)	Yes	Yes	Yes	Yes N=.113	Yes	Yes
Samokhin (2004)	Yes	Yes	No	Yes N=.1238	No	No
Sherman et al (1987)	No	Yes	Yes	Yes N=.639	Yes	Yes
Silva et al (2012)	Yes	Yes	Yes	Yes N=57	Yes	Yes

The methodology scores for the papers reviewed ranged from 4 to 6 of the criteria met. Only six of the papers were written in the last ten years with only 3 of the papers being directly orientated to the study of fracture detection. This highlights the scientific and medical trends in the use of thermology, where the use of thermal imaging went out of favour in the 1990's due the problems associated with it reliability, accuracy and reproducibility (Ammer, 2000)..