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# To review how doctors on duty in emergency departments in South Africa diagnose acute cardiac injury following blunt chest trauma

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# TO REVIEW HOW DOCTORS ON DUTY IN EMERGENCY DEPARTMENTS IN SOUTH AFRICA DIAGNOSE ACUTE CARDIAC INJURY FOLLOWING BLUNT CHEST TRAUMA

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of:

Master of Science in Medicine (Emergency Medicine)

Johannesburg, 2013

**DECLARATION**

I, Giovanni FM Afeltra, declare that this research report is my own work. It is being submitted in partial fulfilment for the degree of Master of Science in Medicine in the branch of Emergency Medicine at the University of the Witwatersrand, Johannesburg. It has not been previously submitted before for any degree or examination at this or any other University.



……...

Giovanni Francesco Maurizio Afeltra

31st day of March 2013

**DEDICATION**

In memory of my father
Mario Umberto Afeltra
1914 - 1990

## ABSTRACT

### INTRODUCTION

Cardiac injury following blunt chest trauma (BCT) presents a clinical spectrum of varying severity ranging from asymptomatic to severe and life-threatening. Attempts to diagnose acute cardiac injury may lead to unnecessary investigations and hospitalisation. Conversely, those patients “not at risk” could potentially be discharged from hospital. This research reviewed what methods are utilised by doctors to identify those patients at risk of acute cardiac injury.

### METHODS

An on-line questionnaire was mailed to doctors working in emergency departments (EDs) throughout South Africa to ascertain what history, examination, and special investigations should be performed on patients presenting with blunt chest injury to exclude cardiac injury.

### RESULTS

These revealed varied responses with inappropriate investigations and lacked unanimity in the diagnostic methods. The majority of doctors did not adhere to up-to-date consensus driven and evidenced based up-to-date practice

There was not much difference in the respondents responses between specialist emergency physicians (SEPs) and general practitioners (GPs).

## CONCLUSION

A high index of suspicion based on careful history taking and physical examination together with specific diagnostic testing limited to identifying those patients at risk of a cardiac injury (and developing cardiac complications) presenting with BCT should be the cornerstone of this diagnostic challenge. It was evident that the diagnosis of acute cardiac injury remains an elusive challenge and lacks consistent utilisation of diagnostic criteria.

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## CONTENTS

**Page**

DECLARATION…….....ii

DEDICATION.....iii

ABSTRACT……..…….iv

ACKNOWLEDGEMENTS……vi

TABLE OF CONTENTS.....viii

LIST OF FIGURES…..……xii

LIST OF TABLES...…….xiv

NOMENCLATURE……...xiv

**TABLE OF CONTENTS**

**CHAPTER 1 ..... 1**

1.0 INTRODUCTION ..... 1

1.1 Study aim and objectives ..... 3

1.1.2 Aim ..... 3

1.1.3 Objectives ..... 3

**CHAPTER 2 ..... 4**

2.0 LITERATURE REVIEW ..... 4

2.0.1 The mechanism of blunt chest injury ..... 6

2.0.2 Pattern of cardiac injury ..... 7

2.0.2.1 Anatomical/structural cardiac injury ..... 7

2.1 Physiological injury ..... 10

2.1 DIAGNOSIS OF BCI ..... 12

2.1.1 CLINICAL FEATURES ..... 13

2.1.1.2 History ..... 14

2.1.1.3 Examination ..... 15

2.1.2 INVESTIGATIONS ..... 18

2.1.2.1 Twelve lead ECG ..... 18

2.1.2.2 Chest X-ray ..... 21

2.1.2.3 FAST and eFAST ..... 21

2.1.2.4 Biochemical cardiac markers ..... 22

2.1.2.4.1 Cardiac Troponins.....22

2.2.2.5 Other Investigations.....26

2.1.2.5.1 Creatine Kinase.....26

2.2.2.5 Creatine Kinase with Myocardial type B fractions.....26

2.1.2.5.3 Echocardiography.....27

2.1.2.5.4 Chest CT-scan.....28

2.1.2.5.5 Other Cardiac Imaging Studies.....29

**CHAPTER 3 .....30**

3.0 METHODOLOGY.....30

3.1 Ethics.....30

3.2 Study design.....30

3.2.1 Measuring tool.....31

3.2.2 Timing.....32

3.3 Contact details of study population.....32

3.4 Inclusion criteria.....34

3.5 Exclusion criteria.....34

3.6 Collection of results.....35

3.7 Sample size.....35

3.8 Data analysis.....35

**CHAPTER 4 ..... 37**

4.0 RESULTS ..... 37

4.1 Demographic Data ..... 37

4.1.1 Question 1: Please indicate if you have a postgraduate emergency medicine qualification/s or attended any of the following course/s.....37

4.1.2 Question 2: Age of the participating doctor.....38

4.1.3 Question 3: Distribution between place of work (Private or Public Emergency Department or both), whether working full-time or part-time, and whether a Specialist Emergency Physician or General Practitioner.....39

4.1.4 Question 4: Distribution by province in which doctor worked in. .....42

4.2 Medical History..... 43

4.2.1 Question 5: General Medical History regarding enquiry about a patient presenting with blunt chest trauma to the emergency department.....43

4.2.2 Question 6: Suspicion of acute cardiac injury after sustaining blunt chest trauma – which of the following questions do you ask the patient? ..45

4.2.3 Question 7: Which FOUR symptoms are considered the most important following blunt chest trauma?.....46

4.2.4 Question 8: The TWO most important symptoms alerting one to the possibility of acute cardiac injury following blunt chest trauma. .....48

4.3 Physical Examination.....50

4.3.1 Question 9: What is regarded as a Major or Minor symptoms on the physical examination that would indicate the possibility of acute cardiac injury following blunt chest trauma? ..... 50

4.4 Question 10: Special Investigations NORMALLY PERFORMED and what IDEALLY should be performed in the diagnostic assessment of acute cardiac injury following blunt chest trauma..... 53

**CHAPTER 5 ..... 56**

5.0 DISCUSSION ..... 56

5.1 Demographic Data ..... 59

5.2 Medical History..... 60

5.3 Physical Examination ..... 65

5.4 Special Investigations ..... 69

5.5 Strengths..……..……..74

5.6 Limitations..... 74

5.7 Source of bias ..... 77

**CHAPTER 6 ..... 79**

5.0 CONCLUSION..... 79

6.1 Recommendations...……81

**REFERENCES ..... 84**

**APPENDICES……..96**

Appendix A: Ethics approval ..... 96

Appendix B: Letter of introduction to all doctors ..... 97

Appendix C: The online survey ..... 99

Appendix D: Troponins ..... 111

Appendix E: FAST ..... 114

Appendix F: The latest recommended guidelines published by the EAST .... 114

**LIST OF FIGURES**

**Figure 1** Postgraduate qualifications……..…..……...36

**Figure 2** Distribution of age……..……... 37

**Figure 3** Distribution between Private and Public Hospitals……...38

**Figure 4** Distribution of Specialist Emergency Physicians and General Practitioners..……....39

**Figure 5** Private Hospital ED split between Specialist Emergency Physicians and General Practitioners…….……....39

**Figure 6** Public Hospital Emergency Department split between Specialist Emergency Physicians and General Practitioners……..……...41

**Figure 7** Distribution by Province..…..……... 42

**Figure 8** Distributions by other provinces..…..……..... 42

**Figure 9** General Medical History Questions asked…...…….. 43

**Figure 10** Distribution of General Medical History respones: Specialist Emergency Physicians vs General Practitioners..…….44

**Figure 11** Questions asked pertaining to Blunt Chest Trauma…….. 45

**Figure 12** Distribution of the FOUR most important symptoms selected……....46

**Figure 13** Distribution of the FOUR most important symptoms: Specialist Emergency Physicians vs General Practitioners…….……...47

**Figure 14** Distribution of TWO most important symptoms chosen for the suspicion of Acute Cardiac Injury following Blunt Chest Trauma..…… 48

**Figure 15** Distribution of the TWO most important symptoms: Specialist Emergency Physicians vs General Practitioners……..……..49

**Figure 16** Distribution of Major and Minor signs……. 51

**Figure 17** Percent difference between Major and Minor signs ……..52

**Figure 18** Distribution of Normal and Ideal Investigations…….54

**Figure 19** Percent difference in distribution of Normal vs Ideal Investigations, and Neither vs Normal plus Ideal Investigations performed…..……..…….55

**Figure 20** Algorithm for the evaluation of Blunt Chest Trauma……..……81

## LIST OF TABLES

**Table 1** Cardiac injuries following Blunt Chest Trauma……..9

**Table 2** Associated Injuries and Incidence in Blunt Cardiac Injury……...17

**Table 3** Electrocardiogram findings in Blunt Cardiac Injury……..20

**Table 4** Detection of clinically significant Blunt Cardiac Injury…….……25

## NOMENCLATURE

ACLS = Advanced Cardiac Life Support ©

AHA = American Heart Association

AIME = Airway Interventions and Management in Emergencies

APLS = Advanced Paediatric Life Support ©

ATLS = Advanced Trauma Life Support ©

BCI = Blunt Cardiac Injury

BCT = Blunt Chest Trauma

BP = Blood Pressure

CXR = Chest X-ray

CK = Creatine Kinase

CK-MB = Creatine Phospho-Kinase with Myocardial Band

CT = Computerised Axial Tomography

cTnI = Cardiac Troponin I

cTnT = Cardiac Troponin T

DIP PEC = Diploma in Primary Emergency Care

EAST = Eastern Association for the Surgery of Trauma

ECG = Electrocardiogram

ECHO = Echocardiogram

ED = Emergency Department

EFAST = Extended Focused Assessment with Sonography in Trauma

EMSSA = Emergency Medicine Society of South Africa

FAST = Focused Assessment with Sonography in Trauma

GP = General Practitioner

HASA = Hospital Association of South Africa

HPCSA = Health Professions Council of South Africa

JVP = Jugular Venous Pressure

LA= Left Atrium

LV = Left Ventricle

MRI = Magnetic Resonance Imaging

PALS = Paediatric Advanced Life Support ©

PMH = Past Medical History

RA = Right Atrium

RBBB = Right Bundle Branch Block

RTA = Road Traffic Accident

RV = Right Ventricle

SEP = Specialist Emergency Physician

S3 = Third Heart Sound

TOE = Trans-Oesophageal Echocardiography

TTE = Trans-Thoracic Echocardiography

# CHAPTER 1

## 1.0 INTRODUCTION

The magnitude of trauma in South Africa is well established being the second overall cause, and the leading non-communicable cause, of death in young adults aged 18 – 24 years of age.[1-4] Trauma accounts for 18% of the caseload presenting to EDs (with 16% of all deaths between the ages of 18 and 40 years of age [2-4]). For every one death that occurs there are 85 serious injuries and 315 minor injuries with about 2.5 million injuries presenting to health facilities every year.[1, 2 ,4, 5, 6] Almost one third of all trauma-related deaths occur after reaching the hospital and approximately 30% of these are considered preventable.[4-6] Epidemiological studies show a wide variation in competence in managing multitrauma patients and have highlighted advantages of properly equipped EDs and trained personnel.[1]

After interpersonal violence, road traffic accidents (RTAs) are the second leading cause of non-natural deaths and every year one out of every fifteen South Africans are injured with 28% of them involved in RTAs accidents and with 41% being pedestrians. A further 25% are passengers in a motor vehicle.[2-4]

RTA mortality incidence in South Africa account for about 15 000 deaths per year and is double the global average in both sexes and in all ages, and with blunt force injury accounting for 10% of this overall cause of death.[2,3] The Hospital Association of South Africa (HASA) believes that “trauma is the largest, deadliest and costliest surgical problem.” [3, 4]

RTAs with vehicular impact, directly or indirectly, accounts for 70% - 80% of all BCT. Acute blunt injury to the heart occurs in up to 20% of all RTA deaths, both in pedestrians and the unrestrained occupant in the vehicle (either the driver of the vehicle or the passenger in the vehicle).[5-7]

The reported incidence of BCT shows a male to female ratio of 4:1. The average age is 41 years (with a range of 3-80 years), with up to 80% the result of a RTA.[4-7] Alcohol intoxication is involved in 39% of all cases.[2-4]

BCT is a significant cause of morbidity and mortality and is seen in 50% of all blunt trauma cases.[3-5] This type of injury is often sudden and dramatic and accounts for 25% of all trauma deaths [2-4]. Up to 60% of these deaths occur after reaching a hospital [2-4] (implying that it may be preventable if recognised) and with less than ten percent requiring surgery.[2-4] BCT accounts for 80% of all chest injuries with the remainder of chest injuries due to penetrative injuries such as gunshots and knife wounds.[5-9]

BCT may involve the anterior chest wall (skin and soft tissue, muscle, bony cage of sternum, ribs and clavicle) and the back (scapula and thoracic vertebrae). The intrathoracic organs (heart, lung parenchyma, pulmonary vasculature, trachea and bronchi), the great vessels including aortic disruption, diaphragmatic rupture and injury to sub-diaphragmatic organs (liver, spleen, bowel) may be involved. BCT is often associated with other injuries (such as head, pelvic, spinal and long bone injury: Table 2).[9, 14, 15, 27-30]

## 1.1 Study aim and objectives

### 1.1.1 Aim

The aim of this research is to assess current practice by doctors working in EDs in South Africa to diagnose acute cardiac injury in a patient subjected to BCT. Are they adhering to current best practice? Are the methods employed accurate, reliable, universal, consistent and appropriate?

### 1.1.2 Objectives

1. To determine which significant predictors (risk factors) would alert the doctor to possible acute BCI in a patient presenting with BCT.
2. To establish what signs and symptoms are considered in assessing for an acute cardiac injury following BCT.
3. To ascertain what investigations are considered important in identifying and diagnosing acute cardiac injury following BCT.
4. To determine the demographics of the participating doctors and post graduate qualifications obtained or course attended and whether practicing as a SEP or a GP.
5. To determine whether there is a difference between SEPs or GPs in the methods of diagnosing acute BCI.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

BCI refers to injury sustained following blunt trauma to the heart. The manifestation/s of such an injury varies greatly from no symptoms and perhaps transient and benign arrhythmias to sudden or delayed death. The extent of the cardiac damage following a blunt force is directly proportional to the amount of kinetic energy created, of which the velocity of the injurious agent is an important factor. Whilst several factors, such as distance from the force, tissue density and site of injury, are considered in estimating the extent of tissue damage, it is generally agreed that high-velocity forces have the potential of inducing injuries with a high index of severity.[6, 17, 46]

Cardiac injury is an often over-looked cause of significant morbidity and mortality (especially in a patient with multitrauma) and is the most frequent unsuspected visceral injury.[4, 6, 7, 8, 9, 31, 32]

The true incidence of BCI is unknown as reported incident rates in the literature vary greatly, ranging anywhere between 8 and 71%.[6] In patients with severe thoracic injury or multiple injuries the actual incidence of BCI may be as high as 76%.[4, 6, 8, 9] Clinical studies looking at BCI in chest and abdominal trauma report incidences significantly lower than in autopsy series.[6-9, 12-16, 31, 32]

This may suggest either that subtler forms of cardiac injury are under-detected when symptoms are minimal, or that many patients with significant BCI die in the pre-hospital setting from either cardiac or associated traumatic injury.[12-16] In 2004 Schultz et al found myocardial contusion to be the most commonly reported form of BCI (60-100%).[9, 22]

The reported incidence of BCI in all BCT patients has a wide variance, from 17% in autopsy series to 70% in clinical reports.[6, 9, 12-16] In different study populations despite similar mechanisms of injury there is a large variation in incidence (3% - 56% - Sybrandy et al. Heart 2003 [50]; 8% - 71% - Clancy et al. Eastern Assoc for Surg and Trauma 2012 [80]; 0 – 76% - MC Ellie. Mt Sinai J Med 2006 [6]; 7% - 76% Schultz [4, 8, 9]).

The absence of a clear definition and gold standard for laboratory testing make the diagnosis of BCI difficult. In addition, the lack of consensus amongst researchers make the standardisation and recommendations in the literature difficult to interpret and the true incidence of cardiac injury difficult to discern since the studies differ in their diagnostic criteria.[9, 10, 11]

### 2.0.1 The mechanism of acute blunt cardiac injury [7, 8, 9, 12, 17, 54]

The heart is well encompassed within the bony thorax comprising the ribs and sternum. A significant force is required to cause BCI and several categories of force are described:

- Direct precordial blow to the chest (a punch with a fist, a kick or due to sporting equipment e.g. a hockey puck). This is a concussive force which tends to be associated with pathologic lesions to the myocardium or coronary vessels and may lead to commotio cordis or dysrhythmias.
- Indirect or bidirectional force (hydraulic effect with a sudden increase in intrathoracic pressure resulting in cardiac chamber expansion and rupture).

This may be a compressive (crush) force between the sternum and thoracic spine that results in an increased intracardiac pressure such as cardiac resuscitative measures whereby external chest compressions may be too forceful.[8, 9]

During an abrupt abdominal compression there is a significant increase in venous pressure which is transmitted to the right atrium (RA) or right ventricle (RV) or by increased retrograde pressure up the aorta and against the aortic valve. These forceful and abrupt pressures from within the thoracic or abdominal cavity distributed to the heart displaces the (right) ventricular wall outwardly, stretching the moderator band and generating a point of high stress around its septal insertion placing the helical endocardial fibre under extreme stress resulting in tears to its structural walls and valves.[6, 12, 17, 18, 19, 23, 24, 25, 56]

- Deceleration or torsion injury (falls from a height – usually more than 6 metres, or the result of an impact in a RTA – the commonest cause of BCI) – causing a tear in the heart at a point of fixation with cardiac rupture.[5-9,12, 18, 22, 24, 25]
- A blast injury (which is a complex cause of polytrauma and includes both blunt and penetrative trauma).
- A combination of any of these forces.

All these mechanisms place multiple intra-thoracic structures and organs at high risk for significant injury in particular cardiac injury, which is the leading cause of death following severe chest trauma. [5-8]

**2.0.2 Pattern of cardiac injury** [6, 7, 9, 13, 14, 16, 20, 22, 31, 32]

Cardiac injury may be anatomical / structural injury (with early complications) and or physiological / microscopic injury – either can result in disturbed pump function with left ventricular dysfunction and cardiogenic shock.

**2.0.2.1** Anatomical / Structural Cardiac Injuries following BCT. [23, 24, 25]

The distribution of injury amongst the different heart chambers relates to the anterior positioning of the right sided chambers, placing them at greater risk of BCI. The right chambers are most frequently injured (accounting for 30% of all injuries).[6, 7, 8] Contusions of the RV and RA (17-32% and 8-65%, respectively) are twice as common as the left ventricle (LV) and left atrium (LA) (8-15% and 0-31%, respectively) owing to their anterior location underlying the sternum (a likely result of a steering wheel injury).[9]

Concurrent injury to more than one chamber is present in over 50% of BCI patients.[9, 13, 22] In those patients with blunt traumatic rupture of the heart, the risk of multiple chamber rupture is over 20%.[9] Of those patients with have a ruptured cardiac chamber, only few reach an ED alive. In addition, a significant reduction in cardiac function may occur in patients with pre-existing cardiac disease.[6, 9]

Blunt trauma can also cause a penetrating cardiac injury which can occur when a sternal fracture (perforates the RV) or a fractured rib (lacerates the RV or LV) resultant from the blunt chest force.[6, 9, 18, 19]

Cardiac rupture, septal defects, coronary artery and valvular injuries occur even more rarely, with only a few case reports documented in the literature (Table 1). Blunt pericardial rupture is rare but may be the most severe form of blunt cardiac injury and may be the result of either a direct impact to the chest or the result of pressure alterations from a compressive force to the abdomen, leading to laceration of the pericardium on both the diaphragmatic and pleural surfaces. It may present as a haemopericardium with cardiac tamponade. Ventricular septal defect presents as a loud holosystolic murmur and cardiac thrill is with severe shock with cardiac failure.[23, 24, 25]

**Table 1** Cardiac injuries following BCT [23, 24, 25]

Cardiac rupture:

- The most severe form of BCI (rare injury with 89% mortality in patients arriving in the ED) - due to increased intracardiac pressure resulting in a myocardial laceration, dissection or aneurysm.
- Shock out of proportion to the injury is the usual presentation

Pericardial injury is usually primarily involved and may result in:

- Haemopericardium.
- Cardiac tamponade.

Valvular injury (with or without injury to the papillary muscles and or chordae tendinae):

- Aortic injury with insufficiency is the commonest (this injury occurs during diastole) – presents with severe congestive heart failure.
- Mitral incompetence (this injury occurs during systole) – progressing to haemodynamic instability.

Coronary artery injury: occurs with direct impact to the left anterior descending artery beneath the sternum leading to:

- Thrombosis, intimal laceration, aneurysm or fistula.
- Presentation: acute myocardial infarction.

**2.0.2.2 Physiological** (or microscopic) injury may vary accordingly. Early complications include electrical conduction defects with dysrhythmias such as ventricular and supraventricular arrhythmias. Dysrhythmias account for 70-80% of complications and 30% of these will present within 72 hours. Rare life-threatening arrhythmias may present after 12 hours.[25] Other arrhythmias include ventricular tachycardia that degenerates into ventricular fibrillation (often fatal), atrial fibrillation (with a poor outcome and the mechanism is poorly understood), atrioventricular, intraventricular defects and sinus node dysfunction. The right-bundle-branch (RBB) is vulnerable to direct injury and prone to result in a RBB-block (RBBB).[6, 9, 10, 11, 20, 21, 25, 30, 31, 32]

Microscopic damage includes direct injury to myocytes with rupture of cells and destruction of cell membranes. These damaged myocardial cells leads to aberrant conduction and contribute to the mechanism of traumatic cardiac arrhythmias.[26] Tearing of muscle fibres and intra-myocardial haemorrhages into the interstitium which may be marginal or diffuse throughout the myocardium may occur. Oedema with necrosis of muscle cells result from consequent release of enzymes from the ruptured of myocardial cells and destruction of the cell membrane. Abnormal perfusion patterns develop from local hypoxia and ischaemia caused by increased intravascular rouleaux formation as a result of the trauma and contribute to the mechanisms of dysrhythmias.[9, 25, 26]

Diffuse hypoxia in areas of contusion, “stunned” myocytes – (leading to decreased myocardial contractility – in 10-20% of patients) and muscle disarray lead to electrical disturbances (rhythm or conduction disturbances) and wall motion disturbances.[25, 26]

Several factors therefore contribute to the decrease in cardiac function and these may vary from electrical disturbances, myocardial hypoxia, myocardial ischaemia (resulting from coronary artery occlusion or injury) and mechanical factors such as valve dysfunction and pericardial tamponade that result in decreased automaticity, decreased cardiac filling, decreased contractility and decreased cardiac output. Impediment to myocardial contractility such as mechanical factors (e.g. pericardial tamponade) and to blood flow (e.g. valvular dysfunction) increases the detrimental effects of muscle function and hypoxia.

Commotio cordis may occur with sudden death (the impact of the external force strikes the heart during the vulnerable period of the cardiac cycle which is 10-30 milliseconds before the T-wave). Therefore, a blunt cardiac impact to the heart timed correctly (and it may be without significant force) may result in cardiac arrest without any signs of structural injury.[5, 6, 8, 9, 17, 20, 23, 26, 54, 56]

Terminologies used:

- Myocardial concussion: a functional damage to the myocardium with no anatomical cellular damage. This injury may be detected by an electrocardiogram (ECG) or echocardiogram (ECHO).
- Myocardial contusion: an anatomical injury to the cardiac musculature with release of biochemical cardiac markers creatine kinase – myocardial band (CK-MB) and Troponins. This injury is assessed by performing an ECG, a blood test, an ECHO, radio-imaging, or it may be found at surgery or autopsy.

The above two account for 90% of all BCI cases.[17, 18, 19, 20, 22, 23, 25, 26, 56]

- BCI: a spectrum of injury incorporating all of the above.

## 2.1 DIAGNOSIS OF BCI

The “gold standard” for the diagnosis of acute BCI is usually at autopsy, clearly not a useful method for the clinician involved in managing a trauma patient.[17, 22] The mechanism of injury as well as the clinical features need to be taken into consideration when diagnosing and managing a patient with suspected BCI. Absence of obvious chest injuries following trauma does not exclude the possibility of blunt injury to the heart.[17] Additionally the diagnosis of a cardiac injury in the presence of hypotension and hypoxia can be easily masked in trauma patients due to other severe injuries haemorrhage, or associated pulmonary contusion, vascular and neurological injuries.[6, 22]

### 2.1.1 CLINICAL FEATURES

Cardiac injury following BCT has a spectrum of clinical manifestations ranging from an asymptomatic and benign myocardial bruise with a transient functional abnormality to structural damage and cardiac rupture resulting in death. Often there are no obvious signs and symptoms of the underlying pathology, which may be life-threatening. A mechanism of injury consistent with BCI, combined with altered cardiac function should provide a practical means of diagnosing cardiac injury. Cardiac injury can be missed due to concomitant bodily injuries and patients with neurological deficits, multiple extremity or organ injuries are at particular risk as their manifestations can mask those of an injured heart and this may be the most common unsuspected fatal injury.[6, 9, 31, 32]

A high index of suspicion, proper triage utilising a combination of history, examination and special investigations for appropriately selected patients may improve the diagnosis, risk stratification and disposition of patients sustaining BCI. Determining which patients require evaluation for BCI following BCT remains nonspecific and inconsistent.[6, 9, 10]

Therefore, few clinical signs or symptoms are specific for BCI. Most patients are asymptomatic or may have only mild symptoms such as palpitations or precordial chest pain (which may be attributed to and/or obscured by musculoskeletal injury) and the physical examination will often be nonspecific. The patient may be haemodynamically stable or unstable.

#### 2.1.1.2 History

The medical history involves establishing significant risk factors that raise suspicion after BCT in determining the risk of possible cardiac injury. The spectrum of presentation ranges from asymptomatic myocardial contusion to symptomatic cardiac injury.

The spectrum of injuries is dependent on significant risk factors: [9, 31, 32]

- Mechanism of injury (i.e. the external force applied to the chest) and the kinetic energy (i.e. the amount of energy transferred to the chest) e.g. the speed of the travelling vehicle. A high speed deceleration injury is the commonest mechanism.
- The time of the injury.
- The age of the patient (> 55 years is considered high risk).
- The use of, or lack there-of, seatbelt restraints and possible steering wheel impact to the chest in motor vehicle accidents, or a damaged steering wheel raises suspicion.
- The presence of chest pain (which is the commonest presenting symptom associated with BCI).[9, 10] This pain may or may be not be anginal in nature.
- The assessment of any cardiac risk factors that may affect the interpretation of the electrocardiograph or mask or confuse any signs of recent cardiac injury. It is essential to obtain a history of ischaemic heart disease, hypertension, diabetes, hypercholesterolaemia, medication (β-blockers, calcium channel blockers), and drug abuse (such as cocaine).

#### 2.1.1.3 Examination

The initial evaluation includes the Primary Survey of the Advanced Trauma Life Support (ATLS ©) guidelines and focuses on assessing and identifying the potential for the six immediately life-threatening injuries related to the airway and the chest.[36]

The Secondary Survey is performed to exclude and identify all possible injuries: The chest for any external signs of sternal or chest wall tenderness and for abrasions or bruising (e.g. “seatbelt sign”), or for imprints of a steering wheel and is palpated for any signs of crepitations, instability or tenderness that might signify fractured rib(s).

Associated thoracic injuries in high velocity impact such as a flail chest, haemothorax, pneumothorax or a fractured sternum (BCI should always be excluded in patients with displaced sternal fractures) clavicle or scapula fractures are common and other associated injuries (Table 2) such as pelvic, head, spinal or extremity injury should always be excluded.[6, 22] Absence of any obvious chest injuries following BCT by no means excludes the possibility of blunt injury to the heart.

Specific cardiac injuries are sought with auscultation of the heart to assess for any adventitious sounds such as a pericardial friction rub, muffled heart sounds, extra heart sounds (such as a third heart sound (S3)), or for any murmur(s) that might indicate vulvar injury and the lungs for any pulmonary wheezing or crackles.[32, 42]

Cardiac tamponade is suggested by Beck's triad: a decline of 10 mmHg or more in systolic BP during inspiration (pulsus paradoxus) with a narrow pulse pressure (< 30 mmHg), muffled heart sounds and distended neck veins and an increased jugular venous pulsation (JVP). Awareness of early complications of BCI. These may be physiological (ventricular and supraventricular arrhythmias and or cardiac failure) or anatomical (myocardial wall rupture with haemopericardium and tamponade, ventricular septum rupture, valvular insufficiencies, intracardiac thrombus resulting in thromboembolic events and coronary artery lesions with acute myocardial infarction).

Assessment of risk factors that require monitoring for cardiac injury following BCT[26] should be identified and are considered in patients at risk for clinically significant BCI: [9, 14, 27, 28]

- Signs and symptoms of arrhythmia, hypotension (systolic BP < 90 mmHg), chest pain, dyspnoea, new murmur, thrill, or pericardial friction rub.
- Associated chest trauma (multiple rib fractures, sternal, scapular fractures, or flail chest, pulmonary contusion, major vessel injury such as aortic rupture and haemo/pneumothorax).
- Mechanism of BCT – a high-velocity impact i.e. a fall greater than six meters or RTA with a travelling speed of more than 30km per hour.[15, 27, 28]

**Table 2** Associated Injuries and Incidence in BCI [7, 9, 13-16, 27-30]

| Associated injuries | Incidence in patients with BCI |
|---|---|
| **Thoracic injury** | |
| Chest pain | 18% to 92% |
| Rib fracture (commonest) | 18% to 69% |
| Aortic or great vessel injury | 20% to 40% |
| Haemothorax | 6% to 64% |
| Pulmonary contusion | 6% to 58% |
| Pneumothorax | 7% to 40% |
| Flail chest | 4% to 38% |
| Sternal fracture | 0% to 60% |
| Both sternal and rib fractures | 28% to 60% |
| **Head injury** | 20% to 73% |
| **Extremity injury** | 20% to 66% |
| **Abdominal solid organ injury** | 5% to 43% |
| **Spinal injury** | 10% to 20% |

## 2.1.2 Investigations

**2.1.2.1 Twelve lead ECG** (ECG findings and incidence in BCI: Table 3)

All patients with suspected BCI should undergo an initial screening admission ECG to exclude any electrophysiological abnormalities. [6, 10, 11, 20, 21, 25, 30, 31, 32.] The ECG may be normal or show nonspecific signs (in up to 80% of admission ECGs) with sinus tachycardia as the most sensitive but not specific finding.[6, 8, 10]

The ECG provides a sensitivity of 100%, a specificity of 50% [8, 10] and a negative predictive value of 90% in the detection of BCI-related complications that require treatment. Use of a right-sided precordial lead does not aid in the diagnosis of BCI.[6, 9]

ECG changes may be due to increased circulating catecholamines, vagal sympathetic reflex, direct damage to conduction pathways or hypoxic areas of the myocardium. Non-cardiac sources includes pain, anxiety, hypoxia, hypovolaemia, anaemia and serum electrolyte disturbances (hypokalaemia). Arrhythmias may also be due to a head injury, alcohol intoxication and patients with pre-existing heart disease.

Arrhythmias on admission correlate with complications in 20% of patients.[7 10, 11]

Rare, life-threatening arrhythmias may present after twelve hours however arrhythmias are most commonly observed in the first 24-48 hours.[21, 22, 24] Serial ECG evaluation is therefore recommended.[9, 21, 22, 24]

Patients with a normal admission ECG may have delayed presentations of cardiac injury. These patients are typically elderly and have pre-existing cardiac disease, multiple severe chest wall injuries and unexplained hypotension.[13, 30, 32, 36]

The prevalence of arrhythmias after myocardial injury is correlated with increased age, pulmonary contusion, rib fractures, extra-thoracic injuries and abnormal findings on the initial ECG. The risk of cardiac dysrhythmias is directly proportional to both the force and speed of impact and inversely proportional to the size of the contact area however there is no correlation between the complexity of arrhythmias and the degree of cardiac injury.[33, 34]

It has been shown that even low energy impact can have immediate and significant effects if applied during a short and vulnerable time interval (i.e. upstroke of the T-wave), resulting in ventricular fibrillation (which is the leading cause of death).[33, 34, 35] Atrial fibrillation is generally associated with a poor outcome.[33, 34]

In a retrospective analysis of 359 patients with blunt chest trauma Biffl WL, et al (1995) [30] identified an abnormal admission ECG (excluding sinus tachycardia) as the most significant independent predictor of a complication defined as dysrhythmias requiring intervention, cardiogenic shock, valvular rupture, or a pericardial tamponade.[8, 23, 81] Eighty percent of these patients are detected on admission to the ED.[81]

.

**Table 3** ECG findings and incidence in BCI. [7, 8, 9, 14, 23, 33, 34, 44, 45, 47, 56, 86]

| ECG finding | Incidence of finding in patients with BCI |
|---|---|
| Nonspecific ECG changes that did not require treatment including:<br>• Sinus tachycardia (commonest)<br>• Sinus bradycardia<br>• Premature atrial contraction<br>• Occasional premature ventricular contraction | 50% to 70% |
| Prolonged QT- interval | 4% to 42% |
| Actual myocardial injury:<br>• ST - or T - wave changes | 2% to 4% |
| New Q-wave | 2% to 15% |
| Conduction delays (Right Bundle Branch Block being the commonest) | 4% to 30% |
| Dysrhythmias requiring treatment:<br>- Atrial dysrhythmias (atrial fibrillation is most common dysrhythmia in BCI)<br>- Ventricular dysrhythmias | 2% to 10% |

#### 2.1.2.2 Chest X-ray

This should be done as a primary screening investigation but it lacks sensitivity and specificity for cardiac injury and is usually done to identify other thoracic injuries, including aortic disruption, bony structure injury (rib/s, sternal, clavicle, scapular fractures), pulmonary contusions, haemothorax and pneumothorax – all of which may be associated with BCI.[9] As many as 60% of patients suspected of BCI will have co-existing injuries that are detected by Chest X-ray.[58]

**2.1.2.3 FAST** (Focused Assessment with Sonography for Trauma) and **eFAST** (extended FAST): [83, 84, 85] (Appendix E)

A rapid (less than 1 - 3 minutes) non-invasive bedside test that has become the standard to expedite diagnostic evaluation and to initiate further management. It should be a first-line test for cardiac evaluation of symptomatic and haemodynamically unstable patients and should be routinely done to obtain an image of the heart and pericardium to exclude an intra-pericardial haemorrhage or pericardial effusion with cardiac tamponade.[9] Multidimensional views performed of the pericardial sac has an accuracy of 97.5%.[46, 83, 84, 85] The eFAST allows for the examination of both lungs by adding bilateral anterior thoracic (pleural cavities for haemo-pneumothorax) and intra-peritoneal sonography to the FAST examination.

#### 2.1.2.4 Biochemical cardiac markers

The ideal biochemical marker for myocardial injury should be specific for myocardial damage, sensitive for early diagnosis and detection of minor myocardial damage and should indicate the prognosis.[10]

##### 2.1.2.4.1 Cardiac Troponins (Appendix D: Tables i-ii)

Cardiac Troponin I (cTnI) and cardiac Troponin T (cTnT) are two cardio-specific myocardial regulatory proteins released into the circulation after loss of cellular membrane integrity of cardiac muscle and are highly specific to myocardial injury. The sole source of cTnI is cardiac muscle (some cTnT is sourced from skeletal muscle) and is thus highly indicative and specific of cardiac injury and has a correlation with ECG abnormalities with a specificity of 100% and 97% (cTnI to cTnT respectively), and a sensitivity of cTnI 23% and cTnT 12% and 12% (cTnI to cTnT respectively).[15, 23, 32, 33, 56, 57, 58]

In haemodynamically stable patients the sensitivity of cTnI (23%) and cTnT (12%) is low and neither provide improved method of diagnosis in BCI.[23, 32, 53, 56, 82, 84, 85]

Although improved specificity of cTn-I and cTn-T compared with conventional markers (creatine kinase (CK) or creatine kinase with myocardial band (CK-MB), the main problem with cTn-I and cTn-T is low sensitivity as well as low predictive values in diagnosing myocardial contusion. cTn-I and cTn-T measurement is currently not an improved method in diagnosing blunt cardiac injury in haemodynamically stable patients.[15, 32, 33, 56]

Moreover, there is no association of post-myocardial contusion cell injury and late outcome in these patients when cTn-I and cTn-T markers were considered.[29, 32, 33] Levels begin to rise within 2-3 hours after injury and peak at 4-6 hours (this peak is earlier and the diagnostic window appears to be smaller than after an acute myocardial infarction). Increased levels may persist for 4-6 days.[15, 29]

Increased levels of troponin have been observed in a large number of clinical settings especially with circulatory failure of septic or haemorrhagic origin in the absence of cardiac trauma and it cannot differentiate myocardial ischaemia.[53, 54, 53] Appendix D: Table i)

Consensus is that CTnI should be routinely measured as a screening test for BCI in patients with suspected BCI.[48, 50, 80, 82] If the results are elevated, the patient should be admitted for monitoring for 24 hours and should be followed up with serial measurements.[23, 32]

The ideal timing for troponin assays is not yet determined and a secondary measurement at 4-6 hours and at 24 hours (since there is no consensus on this time) is necessary to reliably exclude cardiac injury – especially if the troponin concentrations are within reference ranges on admission shortly after the trauma.[8, 52, 82, 84, 85]

Relos, et al. (2003) [51] found that even a moderate increase in serum Troponin I was indicative of a four-fold mortality increase in surgical patients. In addition, these troponins have also proved to be useful in the stratification of patients at risk for complications.[52]

A normal concentration of cardiac troponin I or T has been reported by several investigators to be a strong indicator for the absence of cardiac injury in patients with blunt chest trauma.[29, 50, 56, 59, 60] Comparisons of troponins as a screening test for clinically significant BCI involved several studies by various notable investigators.

Fulda G, et al. (1997) [18] found that initial ECG abnormalities and Troponin T were the only variables that significantly predicted clinical cardiovascular compromise and that abnormal troponins correlated with abnormal ECG

Salim A, et al. (2001) [44] concluded that the sensitivity of an abnormal ECG and elevated cTnI for clinically significant BCI is 100% (Normal ECG and serial cTnI measurements: (no risk of BCI), Abnormal ECG and elevated cTn I (sensitivity for likely risk of BCI was 100% and positive predictive value was 62%).

Kaye P, et al. (2002) [71] concluded that cardiac troponins seem to be highly specific and sensitive for myocardial injury.

Velmahos G, et al. (2003).[25] Serial ECG and cTnI analysis were performed. Key results: no patients with a normal ECG and cTnI were deemed to have significant BCI (Normal ECG and Troponin I (over 8 hours): 100% negative predictive value, abnormal ECG and Troponin: 34% positive predictive value, abnormal ECG and Troponin I with risk factors: 75% positive predictive value).

Sybrandy KC, et al. (2003).[55] All patients with suspected cardiac injury was studied utilising cTnI measurement to detect myocardial contusion.

All patients with a normal cTnI had no complications, Sensitivity of 100% (all those with a normal TnI had no problems). Specificity of 83.5% - 87.5%

Collins J, et al. (2009) [9] concluded that obtaining cTnI (sensitivity of 100%) with a normal ECG is unnecessary and If the admission ECG has minor abnormalities and the cTnI at 4-6 hours after the injury is normal, then risk of BCI-related complications is low.

Diagnosis of BCI should not rely completely on presence of elevated cTnI or cTnT, but supported by presence of significant ECG abnormalities.

A consensus of utilising an admission ECG together with Troponin I measurement have been accepted to rule out any significant acute cardiac injury.[22, 25, 52, 59, 80, 82]

**Table 4** Detection of clinically Significant BCI.[82, 85, 86]

| | TnI (%) | ECG (%) | TnI and ECG (%) |
|---|---|---|---|
| Sensitivity | 73 | 89 | 100 |
| Specificity | 60 | 67 | 71 |
| Positive predictive value | 21 | 29 | 34 |
| Negative predictive value | 94 | 98 | **100** |

#### 2.1.2.5 Other investigations

The following investigations were mentioned either because of their previous utility or to specify its specific indication for diagnosing BCI.

##### 2.1.2.5.1 Creatine Kinase (CK).

CK is nonspecific and limited with poor sensitivity, specificity and positive predictive value in relation to clinically significant blunt myocardial injuries. CK shows many false positives as it is increased in skeletal trauma (and more specific to the chest wall injury) and is therefore of limited value and not useful for diagnosing BCI.[6, 8, 11, 18, 28, 29, 30, 32, 52]

##### 2.1.2.5.2 Creatine Kinase with Myocardial type B fractions (CK-MB)

An isoenzyme of CK and is isolated in skeletal and cardiac muscle, in addition to lung, stomach, pancreas, liver, small intestine, and colon and its release during trauma can confound the interpretation of the value measured. False positive elevation can be due to skeletal muscle injury, cardioversion, cardio-pulmonary-resuscitation and cocaine abuse.

It has a low sensitivity (40%-50%) and a low specificity for complications and is abandoned as a screening tool for BCI.[9, 29]

Several studies compared the utility of CK, CK-MB, cTnI, cTnT and determined that their measurement (CK-MB, CK-MB/CK total ratio, CK-MB mass and CK-MB mass/CK) were not useful in the assessment to detect myocardial injury after blunt chest trauma and have no prognostic value.[6, 8, 11, 28, 29, 30, 32, 52]

#### 2.1.2.5.3 ECHO

Most of the data analysed suggest that the utilisation of ECHO as a primary screening test for clinically significant BCI in haemodynamically stable patients was not useful and should not be routinely performed to detect BCI in patients with BCT and should rather be reserved for patients with clinical compromise.[6, 22, 28, 57, 74-78, 82] It should rather be recommended as a diagnostic test in patients who present with cardiac failure, unexplained hypotension (or haemodynamic instability) or arrhythmias.[44, 46, 76, 82]

In these instances ECHO is a valuable tool to assess cardiac function and to detect motion wall abnormalities, valvular disruption, pericardial effusion, and myocardial contusion (defined as akinetic or dyskinetic regional wall abnormalities). The literature also supports reserving echocardiogram for symptomatic patients even with a significant mechanism of injury.[82]

Thus echocardiography should be reserved as a complimentary rather than primary screening tool for BCI. Trans-oesophageal (TOE) and Trans-thoracic Echocardiography (TTE) [31, 44, 46, 76, 82] do not correlate with ECG nor enzyme changes and do not predict complications.[74-78]

TOE seems to be more sensitive and specific and should be the test of choice in patients with high clinical suspicion for BCI – however it is invasive and requires sedation and possible intubation. TTE is difficult to perform in the presence of severe chest wall injuries, pleural tubes, mechanical ventilation and the obese patient.

#### 2.1.2.5.4 Chest CT-scan

Computerised axial tomography (CAT / CT) has become routine in patients with a significant mechanism of injury. The current literature indicates that in blunt trauma patients with an abnormal physical examination, abnormal chest X-ray, or ultrasound examination of the chest, CT-scan is likely to reveal relevant chest injuries.[78]

Multidetector CT with ECG-gated capabilities provides a heightened sensitivity and specificity to the diagnosis of BCI. This has the ability to accurately distinguish types of injury to the myocardium (similar to that of MRI.

CT can identify very small pericardial effusions and pericardial tears. In combination with coronary angiography, coronary anatomy, myocardial function and perfusion can be gauged. There was however, no strong evidence to suggest that CT chest could be omitted in patients without these criteria or whether these finding are in fact beneficial for patients.[79]

Significant predictors of an abnormal CT-chest after BCT (147 original articles on blunt chest injury that was evaluated revealed the following): [78]

- Abnormal chest ultrasonography (most accurate predictor for chest injury).
- Abnormal physical examination (abnormal respiratory effort, reduced air entry, chest wall tenderness, coma, need for assisted ventilation).
- Pelvic fractures.
- Presence of any injuries on the conventional Chest X-ray.

### 2.1.2.5.5 Other Cardiac Imaging Studies

**Cardiovascular (MRI)** in the detection of myocardial injury is not established. This modality requires a stable patient, is costlier and the quality varies from institution to institution.[79]

### Radio-nucleotide Perfusion Scans

Radionuclide scans assess perfusion of the contused area but it has no advantage over ECG or Echo and it is not useful in the evaluation of BCI or in predicting complications.[79, 80] It has been also shown to have no correlation with clinical outcome following BCT and is not recommended as a test to diagnose BCI.[80]

The diagnosis and management of BCI in trauma patients has challenged clinicians for decades. A high index of suspicion based on careful history taking and examination and with specific diagnostic testing limited to identifying those patients at risk of a cardiac injury (and developing cardiac complications), in a patient presenting with blunt chest trauma, should be the cornerstone of this diagnostic challenge.[3-9]

ECG alone is not sufficient to rule out BCI. Based studies showing that the addition of troponin I to ECG improved the negative predictive value to 100%, the recommendation is obtaining an admission ECG and troponin in all patients in whom BCI is suspected. BCI can be ruled out only if both ECG result and troponin I level are normal. Patients with new ECG changes and/or elevated troponin should be admitted for monitoring.

# CHAPTER 3

## 3.0 METHODOLOGY

### 3.1 Ethics

Ethics was granted from the University of the Witwatersrand to perform this research survey (Clearance Certificate: M10M101117: Appendix A).

### 3.2 Study design

This was a prospective, descriptive, cross-sectional, quantitative study using an on-line questionnaire. The survey was hosted by www.SurveyMonkey.com as the internet portal to perform the online survey (Appendix C). The e-mail invitation contained a link to the internet-based questionnaire. A letter of introduction (Appendix B) that included the link to the website (thereby granting consent for the answers to be included in the study and an assurance that the answers are kept completely confidential) was e-mailed to 776 doctors working in EDs.

An attempt was made to evenly distribute the questionnaire to doctors working in both the Public and Private Hospital EDs throughout the nine provinces of South Africa. The design of the questionnaire sought to obtain data on the demographics of the participating doctor such as any post-graduate qualifications obtained and courses completed in emergency medicine, their age, their location of work (whether they worked in a Private ED or Public ED, or both) and as to whether they practiced as a SEP or as a GP.

Clinical questions that would alert one to the possibility of a cardiac injury included the general medical history (and what significant predictors that would alert the possibility of BCI following BCT), the physical examination and the special investigations - those normally performed and those that ideally should be performed - on patients to exclude BCI in those patients presenting with BCT.

The questionnaire contained 10 closed-ended questions written in Active Server Page and used JavaScript to verify the authenticity of responses. Six hours of programing time was required to implement the questionnaire on the Internet and establish the underlying database. Data from completed forms were inserted into an SQL database automatically and were then imported onto a Microsoft Excel spreadsheet for analysis.

To complete the survey, respondents were required to answer questions by clicking in specific buttons that represented points on a Likert scale. Users scrolled down the entire questionnaire and finally clicked on the 'submit' button when the survey was completed.

### 3.2.1 Measuring tool

The measuring tool was an on-line survey consisting of a choice of ten closed-ended questions directed at the participating doctor to determine how they would establish acute cardiac injury following BCT.

Some questions had little or no significance or relevance in assessing a patient with blunt chest trauma and were purposfully included in order to avoid leading the participant (to avoid bias) to the selection of an answer.

Some questions were more relevant or significant than others but due to the lack of a clinical gold-standard there were no absolute correctness to the answers. However, it was important to establish what the doctors were currently practicing in their EDs, and is it according to “best practice.”

### 3.2.2 Timing

The online survey was opened and sent out to the first group of doctors on the 7th November 2011. Completed questionnaires with the first responses appeared on the same day. Of the 776 e-mail invitations sent, 88 were rejected by the server due to e-mail addresses being either incorrectly spelt or no longer valid. After the initial e-mail invitation, the adjusted response rate, accounting for invalid e-mail addresses and lost data, was just under 10%. Reminders were sent two months after the initial invitation, and a further two sent four and eight months later. The survey was closed on the 15th August 2012.

## 3.3 Contact details of study population

The contact information regarding the study population of doctors were obtained from various resources: The doctors working in these EDs (private and public) were invited via e-mail to partake in this research survey.

- Doctors registered as postgraduate students reading for the degree in Master of Science in Medicine (Emergency Medicine) in the Division of Emergency Medicine, Faculty of Health Sciences at the University of the Witwatersrand.

- Specialist Emergency Physicians in the Divisions of Emergency Medicine at the Universities of the Witwatersrand and Cape Town.

  Doctors who are registered members with the Emergency Medicine Society of South Africa (EMSSA).
- Specialist Emergency Physicians registered with the Health Professions Council of South Africa (HPCSA).
- Medical doctors who work in private Emergency Departments and or public Hospital Emergency Departments.

**Private Hospitals**: a list of all the Emergency Departments was obtained from the main private hospital groups. In many incidences each hospital had to be contacted individually in order to obtain the contact details of the doctors. The hospitals were represented in all the provinces and included:

  - Netcare Group LTD.
  - Mediclinic Corporation – Southern Africa.
  - Life Healthcare Group Holding LTD.
  - National Hospital Network (NHN).
  - Lenmed Hospital Group.

**Public Hospitals**: a list of “Hospitals Accepted for DIP PEC (SA) Training” was obtained from the College of Emergency Medicine of South Africa. This provided a useful and comprehensive list of public hospitals, (both teaching and non-teaching) in all the provinces and the prescribed requirements such as:

- a 24-hour emergency / casualty department,
- a full-time senior medical officer in charge,
- Specialists on-call.

### 3.4 Inclusion criteria

- Doctors registered with the HPCSA
- Doctors with or without a postgraduate qualification/s and / or course/s in emergency medicine.
- Doctors who may be either a Specialist or a General Practitioner.
- Doctors working in Emergency Departments.
    - Doctors working in either private or public Emergency Departments.
    - Doctors working either full-time or part-time in Emergency Departments.
- Doctors working in all nine provinces of South Africa.

### 3.5 Exclusion criteria

- Doctors not involved in Emergency Medicine.
- Doctors not working in Emergency Departments.
- Doctors not working in South Africa.
- Failure to obtain consent.

### 3.6 Collection of results

#### 3.6.1 Sample size

This was a descriptive study and the response rate to the online survey was anticipated to be poor. This was considered to be a small study yet the sample size would be representative of what was currently practiced by doctors working in the ED. For a small study a wide confidence interval was accepted and P-values were not relevant. Taking the number of doctors on my mailing list (776 doctors), the sample size was determined by a margin error of 9.78%, a confidence level of 95% and a confidence interval of 9.15. The actual response rate was 16% and this provided a sample size of 100 completed answers (an acceptible response rate). On-line medical survey response rates normally varies between 20 – 30%. This figure could be achieved and would be a representative sample size that could provide a review as to how doctors in the ED establish the diagnosis of BCI in patients presenting with BCT.

#### 3.6.2 Data analysis

This was performed by utilising descriptive, retrospective, nonparametric, collaborative and multivariate statistics.

This was done in several phases and the purpose of the data analysis was to investigate associations between the various variables. The results of the completed questionnaires were downloaded on-line and analysed. The data was cleaned (to prevent and correct errors from problems that might have occurred when the data was entered and stored).

An initial data analysis was performed by checking the quality of the data using descriptive statistics. There were no initial transformation of variables as the distribution did not differ from the norm. The characteristics of the data sample were assessed by correlations and associations and basic statistics of variable and cross-tabulations.

The main data were analysed. Variables were defined and basic coding were performed. The results were collated, assessed and analysed by determining the various categorical and nominal variables and placed onto an excel spread-sheet. Univariate data analysis were performed to check the quality of the data and to put them into tables. Measurement levels of the variables were taken into account for the analysis and this included frequency counts and associations (cross tabulations and log-linear analysis). Stability of the results were checked by cross validation and the statistical method used was the general linear model, Anova (analysis of variation).

The data analysis were performed using the SPSS (Statistical Product and Service Solution – version 20.0: 2011) statistics data editor.

# CHAPTER 4

## 4.0 RESULTS

### 4.1 Demographic Data

#### 4.1.1 Question 1: Please indicate if you have a postgraduate emergency medicine qualification/s or attended any of the following course/s.

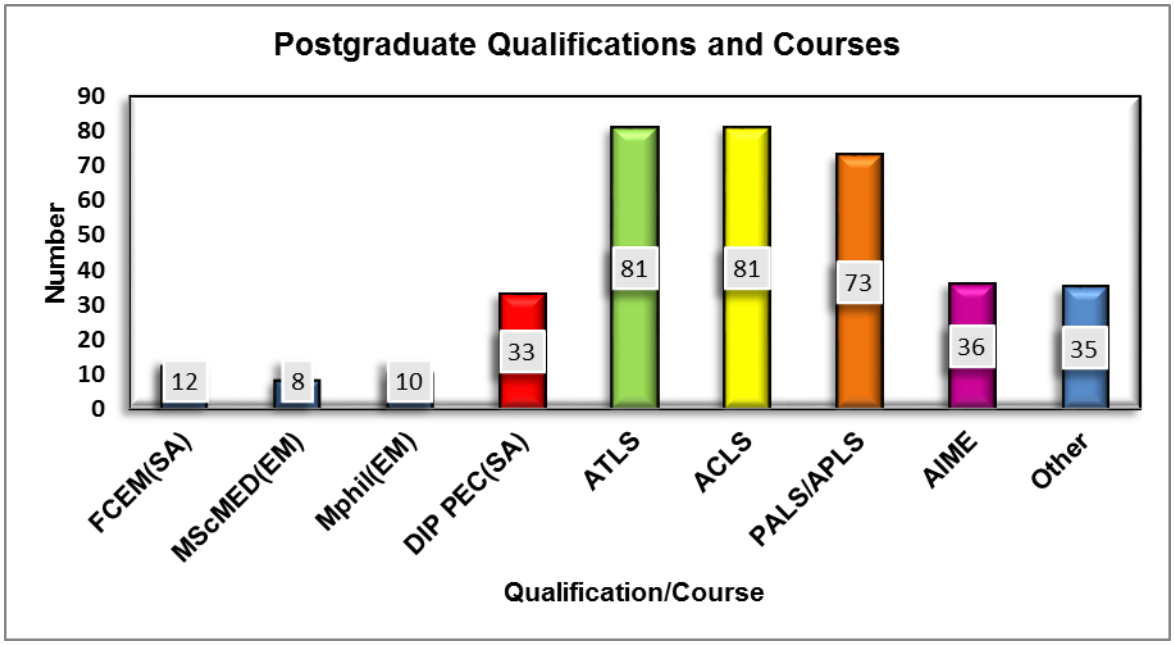


**Figure 1** Postgraduate qualifications and courses.

### 4.1.2 Question 2: Age of the participating doctor

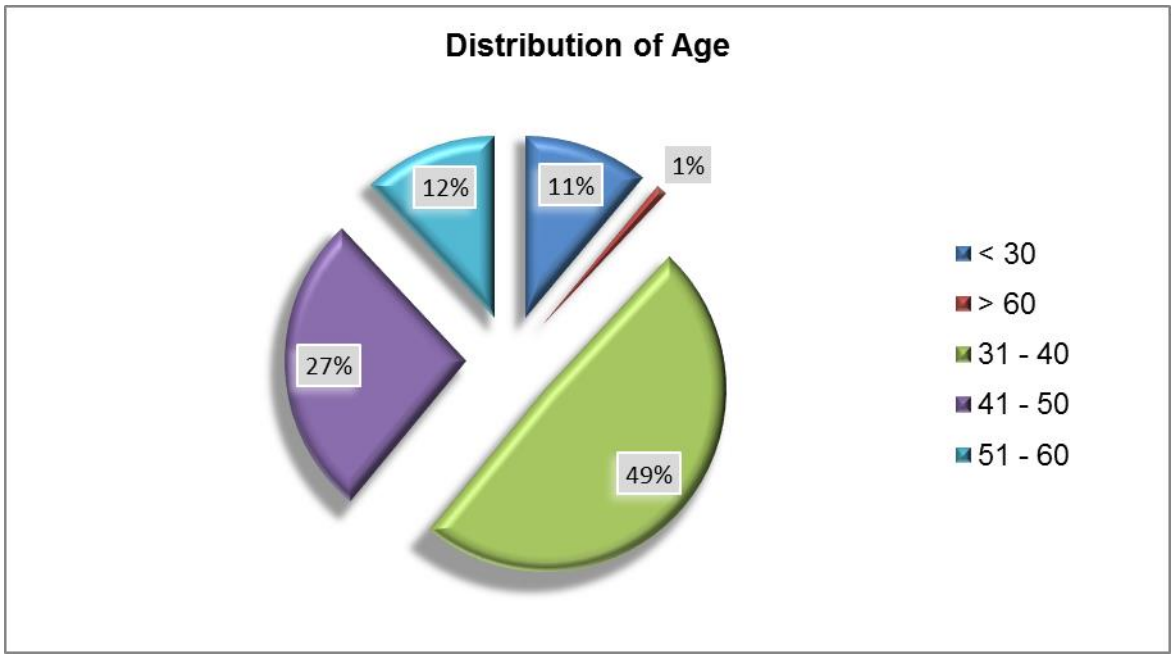


**Figure 2** Distribution of age of the participating doctor.

### 4.1.3 <u>Question 3</u>: Distribution between place of work (Private or Public Emergency Department or both), whether working full-time or part-time, and whether a Specialist Emergency Physician or General Practitioner.

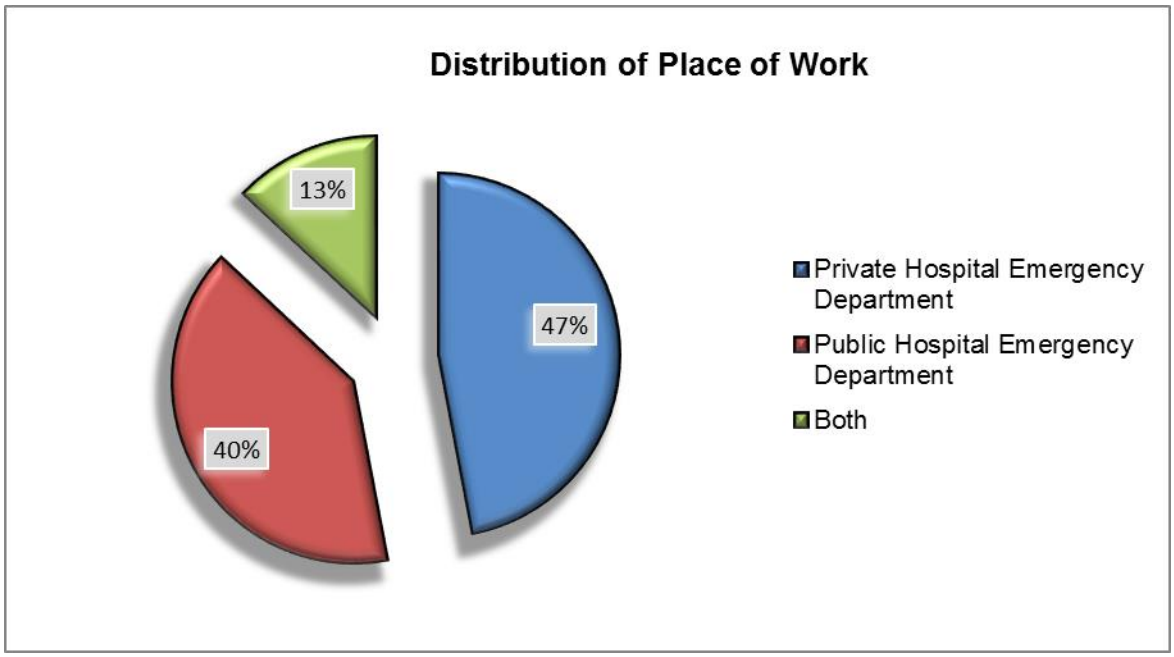


**Figure 3** Distribution between Private and Public Hospital Emergency Department.

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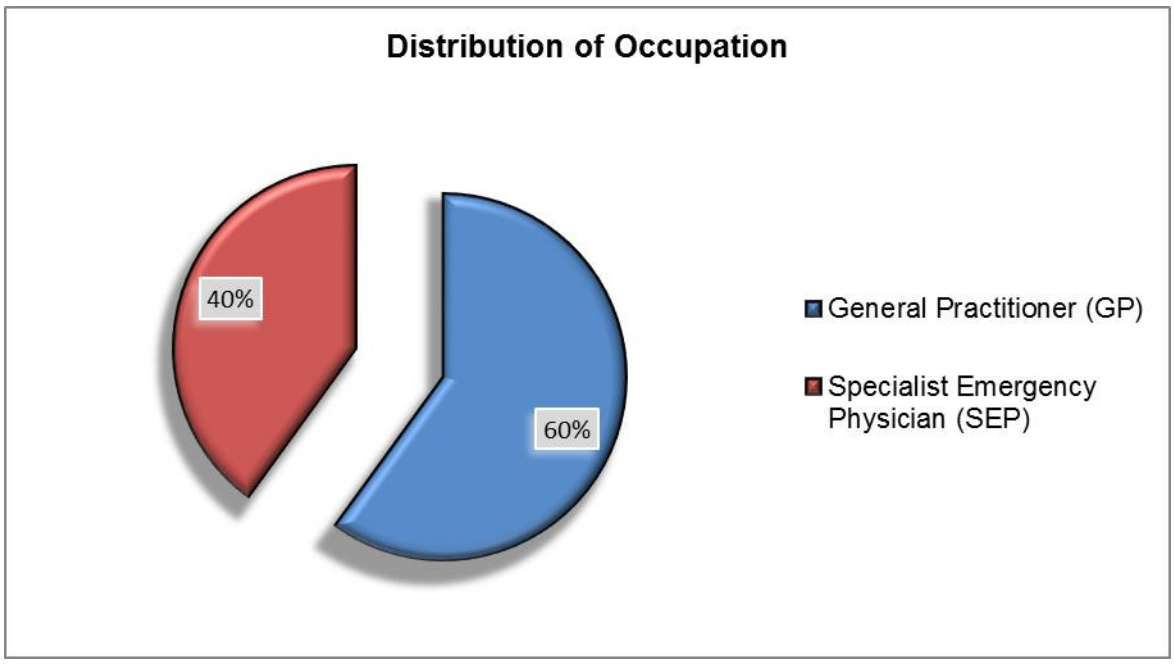



**Figure 4** Distribution of Occupation: SEP and GP.

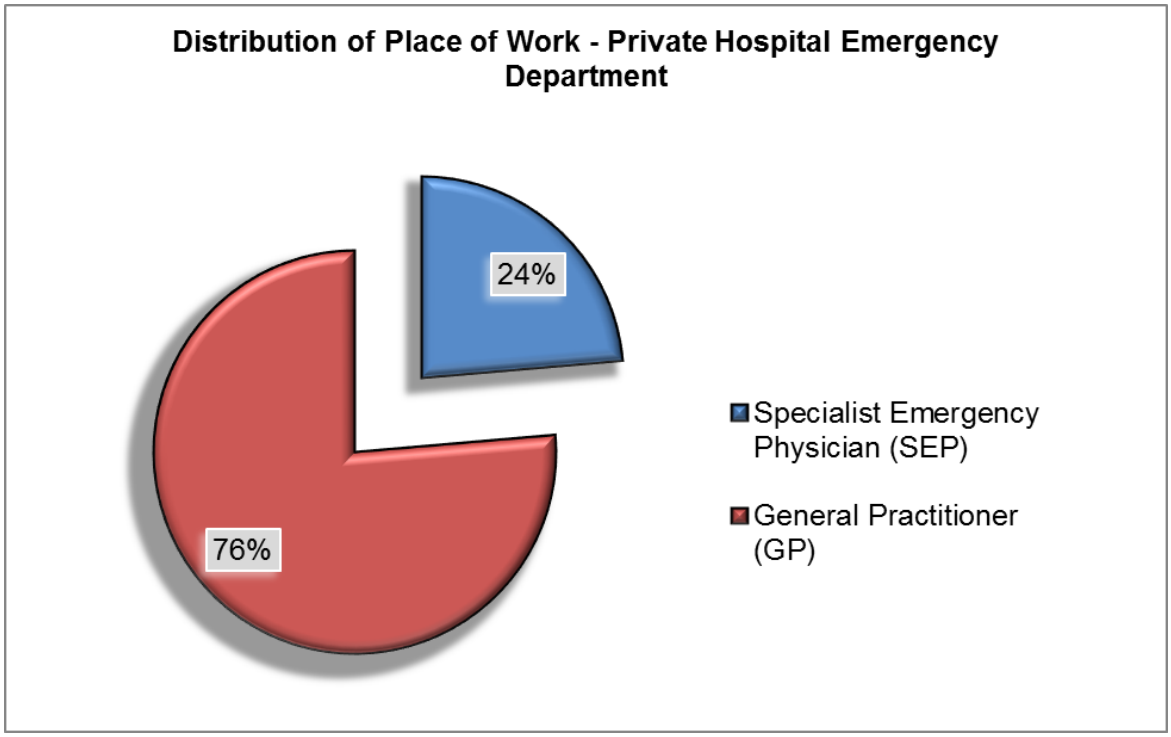



**Figure 5** Private Hospital Emergency Department: SEP and GP split.

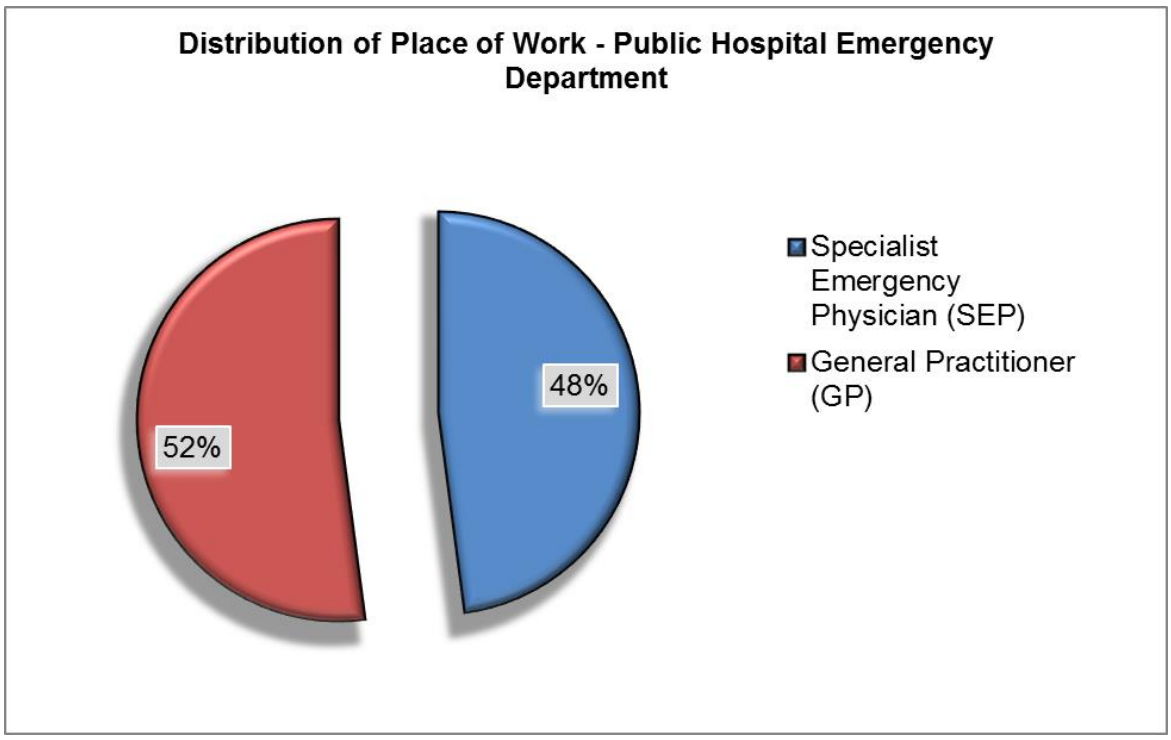
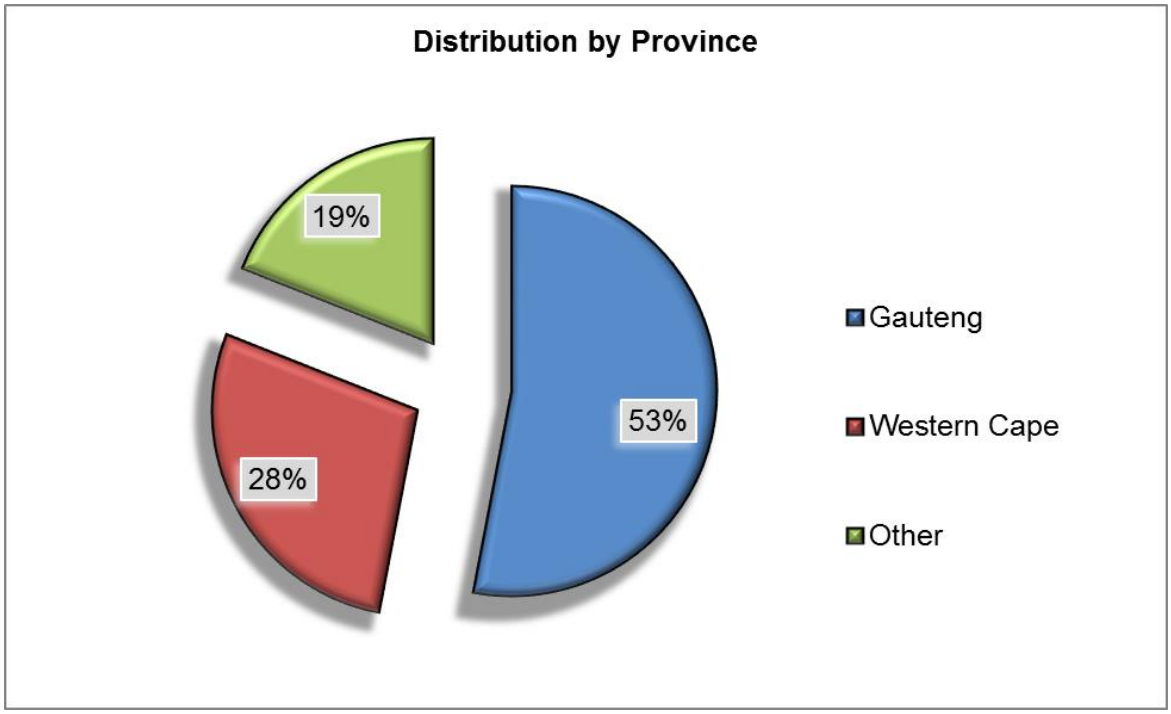
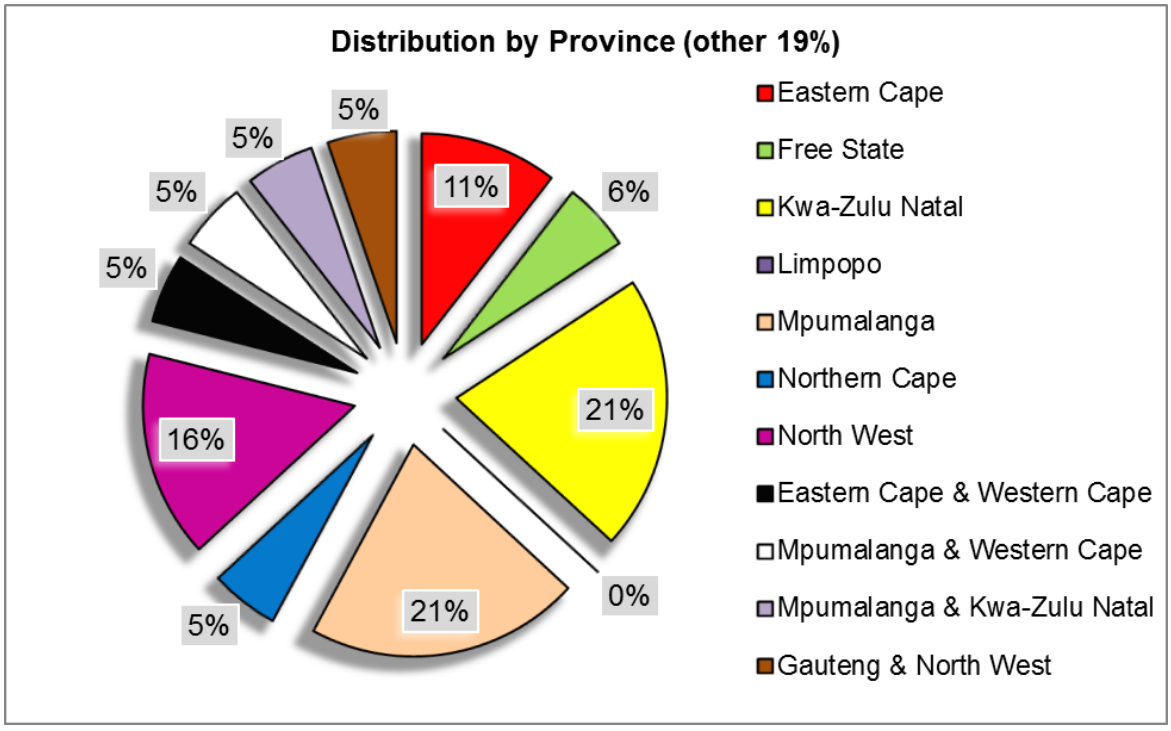



**Figure 6** Public Hospital Emergency Department: SEP and GP spit.

### 4.1.4 Question 4: Distribution by province in which doctor worked in.




**Figures 7 and 8** Distribution by Province and "other" provinces.

## 4.2 Medical History

### 4.2.1 Question 5: General Medical History regarding enquiry about a patient presenting with blunt chest trauma to the emergency department.

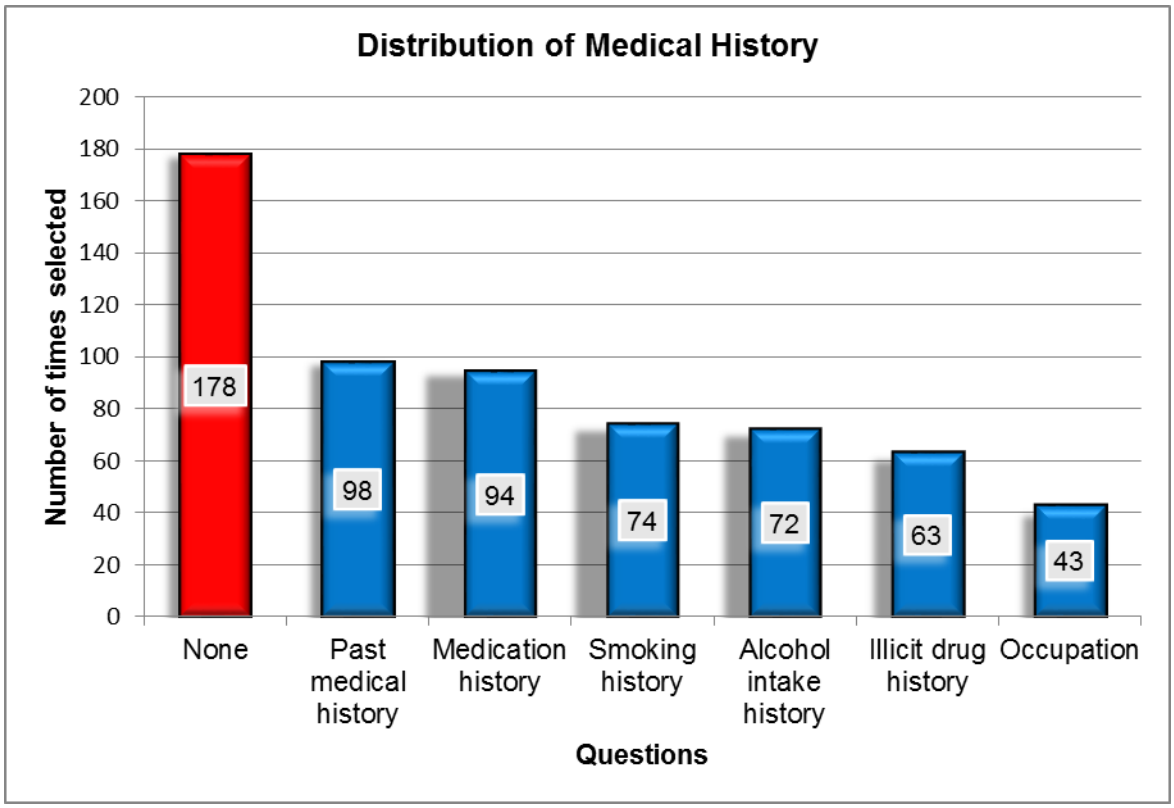



**Figure 9** General Medical History Questions asked and "none" asked.

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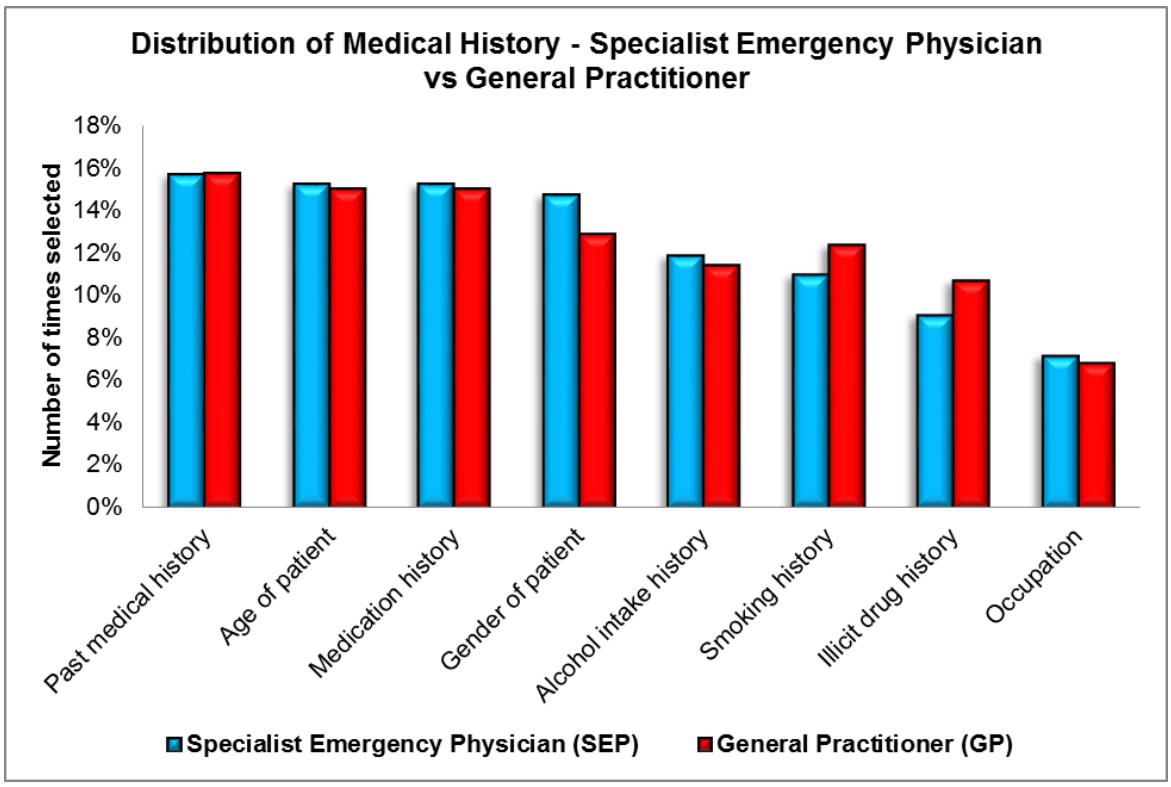



**Figure 10** Distribution of General Medical History: questions asked by Specialist Emergency Physician vs General Practitioner.

### 4.2.2 Question 6: Suspicion of acute cardiac injury after sustaining blunt chest trauma – which of the following questions do you ask the patient?

A choice of six questions pertaining to blunt chest trauma was provided:

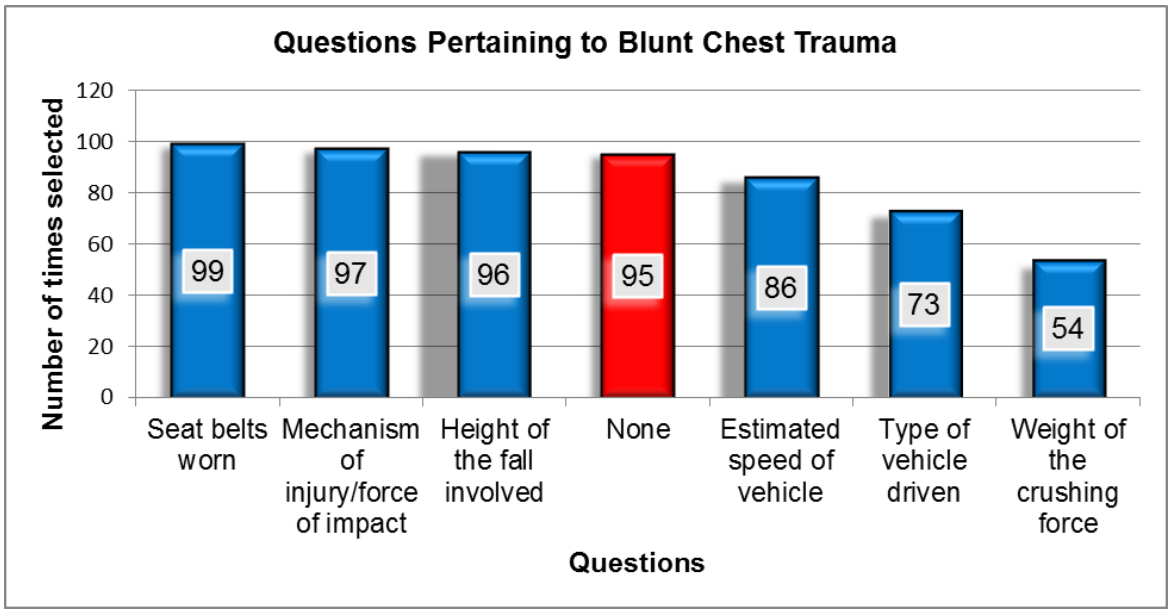



**Figure 11** Questions asked pertaining to Blunt Chest Trauma.

### 4.2.3 <u>Question 7:</u> Which FOUR symptoms are considered the most important following blunt chest trauma?

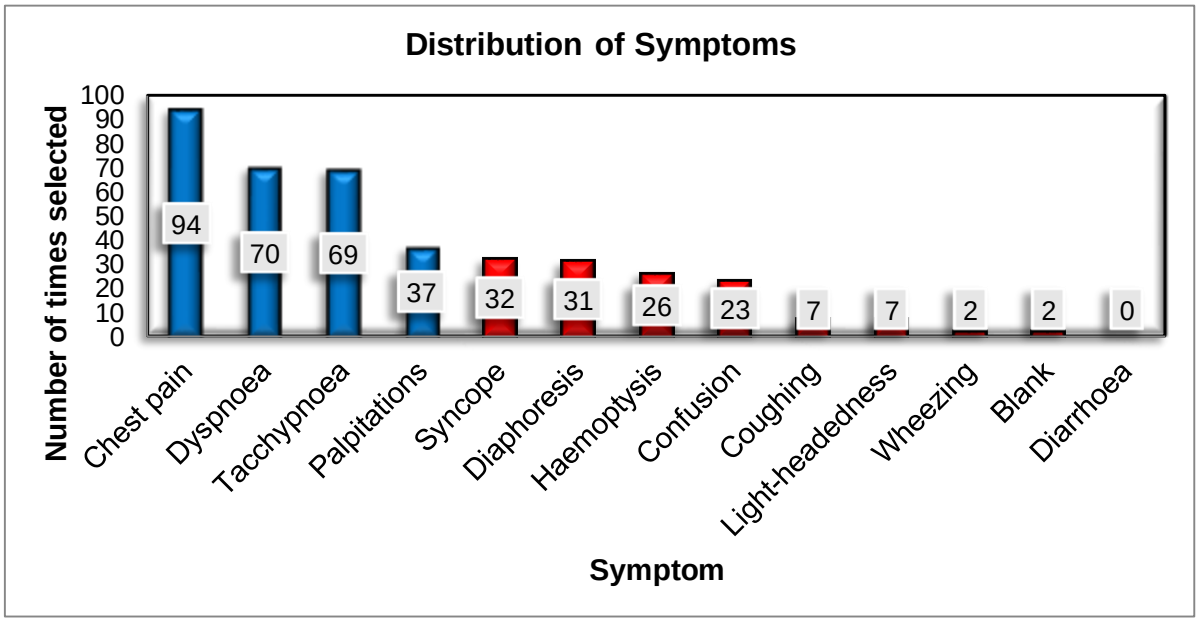



**Figure 12** Distribution of the FOUR most important symptoms.

Note: the maximum percentage times selected cannot exceed 25% since a maximum of four symptoms were required to be answered. That is, if a symptom was asked for by all respondents, this symptom would represent 25% of all responses.

Comparison of the responses between SEPs and GPs.

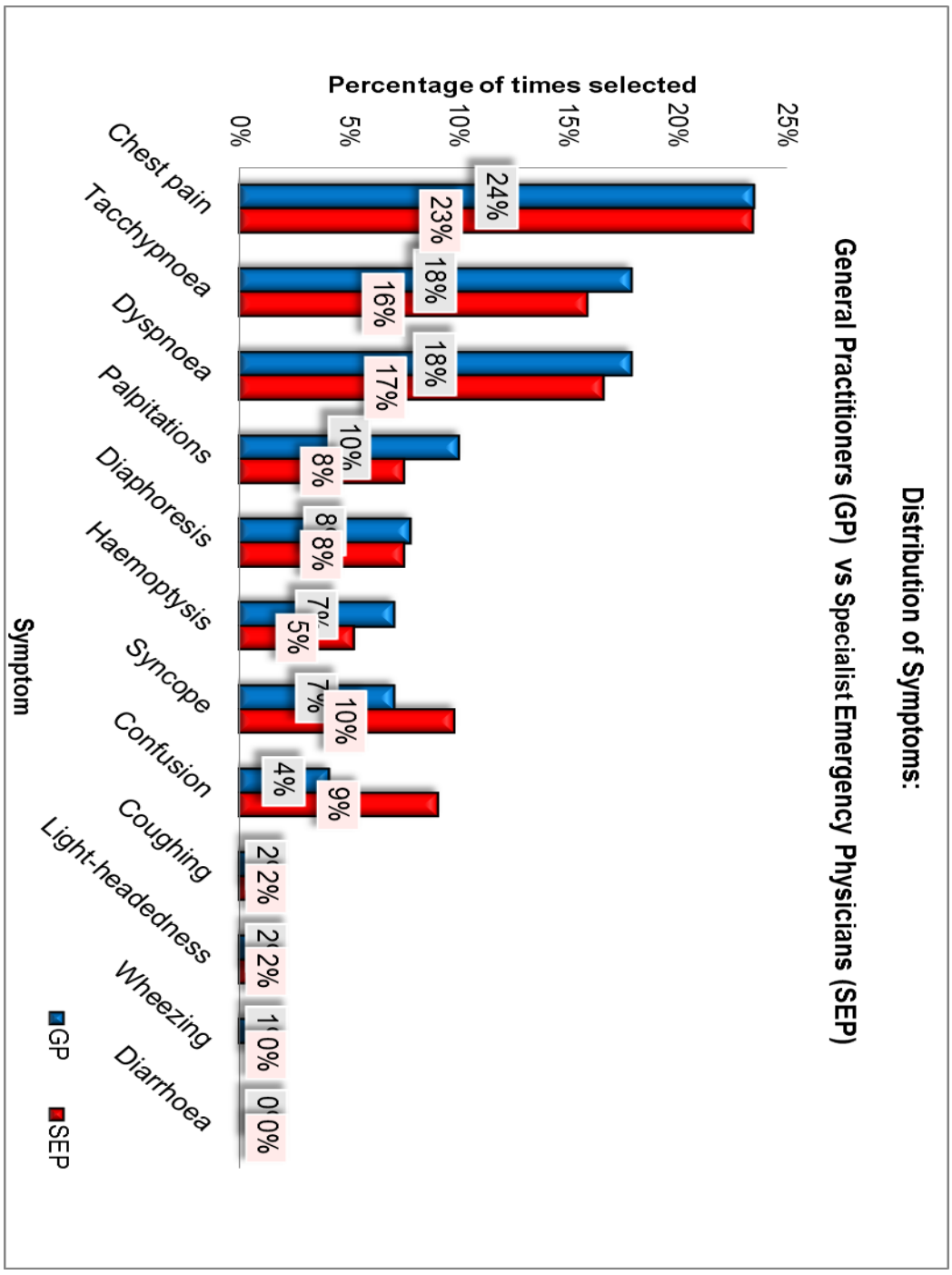



**Figure 13** Distribution of the FOUR most important symptoms: Specialist Emergency Physicians vs General Practitioners.

### 4.2.4 <u>Question 8</u>: The TWO most important symptoms alerting one to the possibility of acute cardiac injury following blunt chest trauma.

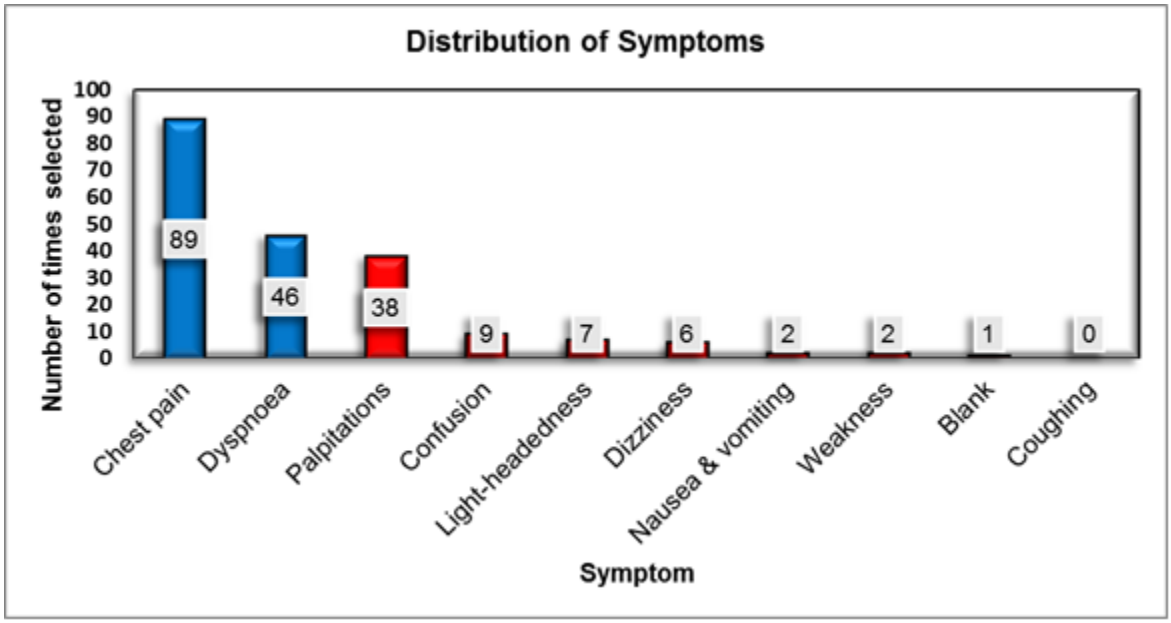



**Figure 14** Distribution of TWO most important symptoms chosen for the suspicion of Acute Cardiac Injury following Blunt Chest Trauma.

Note: the maximum percentage times selected cannot exceed 50% since a maximum of two symptoms was required for the answer. That is, if a symptom was asked for by all respondents, this symptom would represent 50% of all responses.

A comparison of the responses is made between Specialists and GPs in their selection of the TWO most important symptoms.

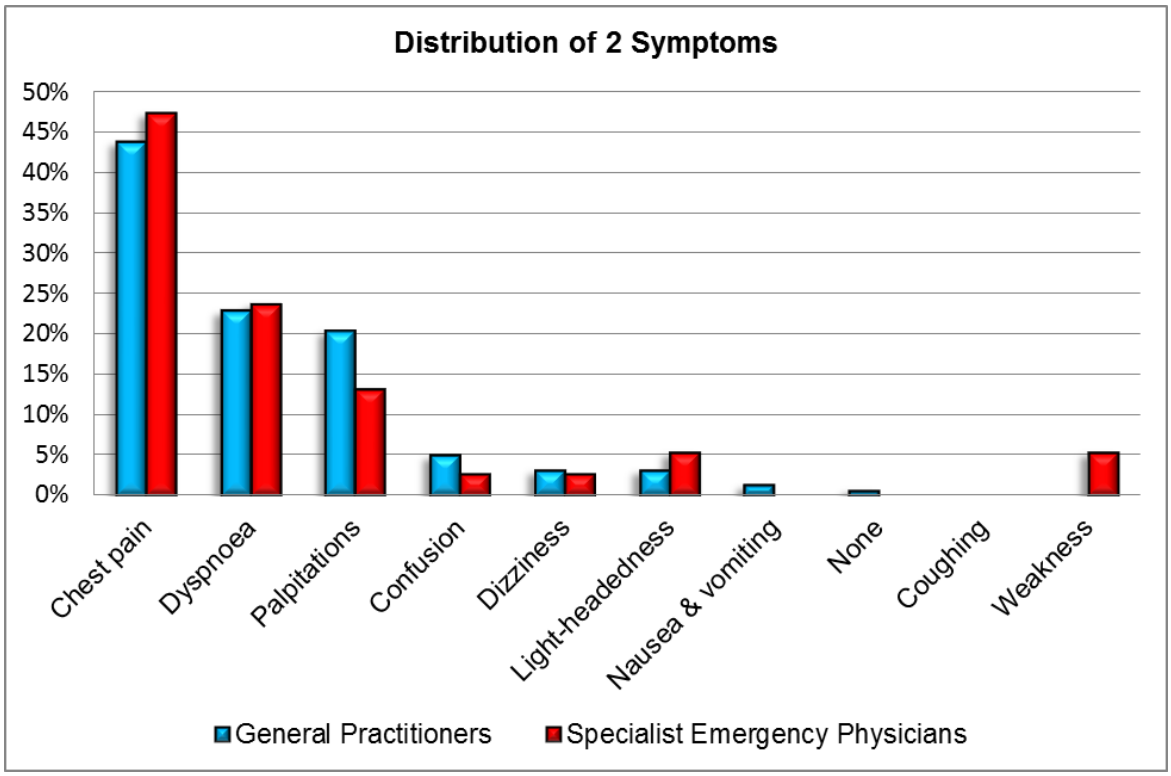



**Figure 15** Distribution of the TWO most important symptoms: Specialist Emergency Physicians vs General Practitioners.

### 4.3 Physical Examination

#### 4.3.1 Question 9: What is regarded as a Major or Minor symptoms on the physical examination that would indicate the possibility of acute cardiac injury following blunt chest trauma?

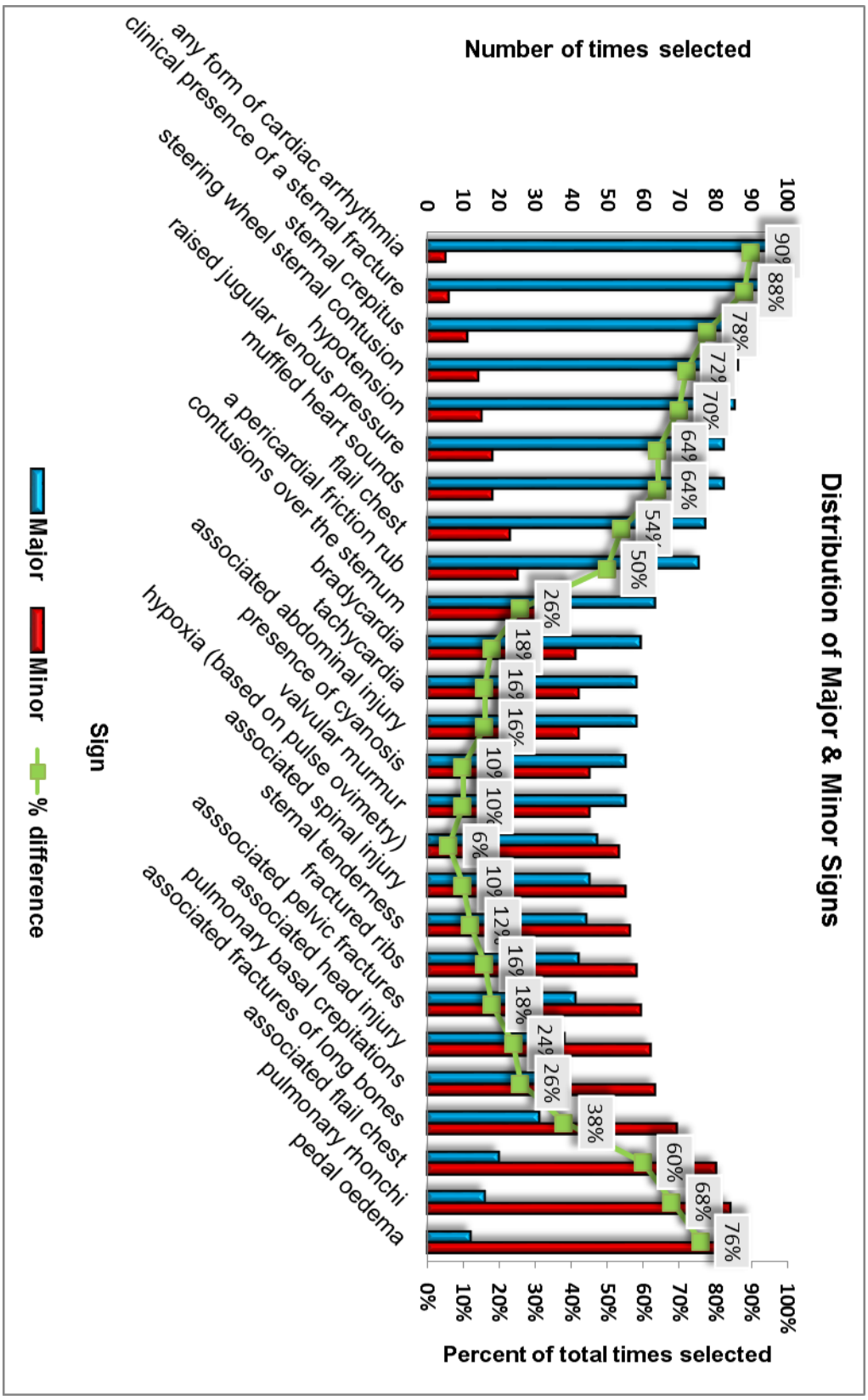
A choice of a possible 26 signs encountered on physical examination that could be considered either as a major sign or as a minor sign suggesting the possibility of acute cardiac injury in a patient presenting with BCT.

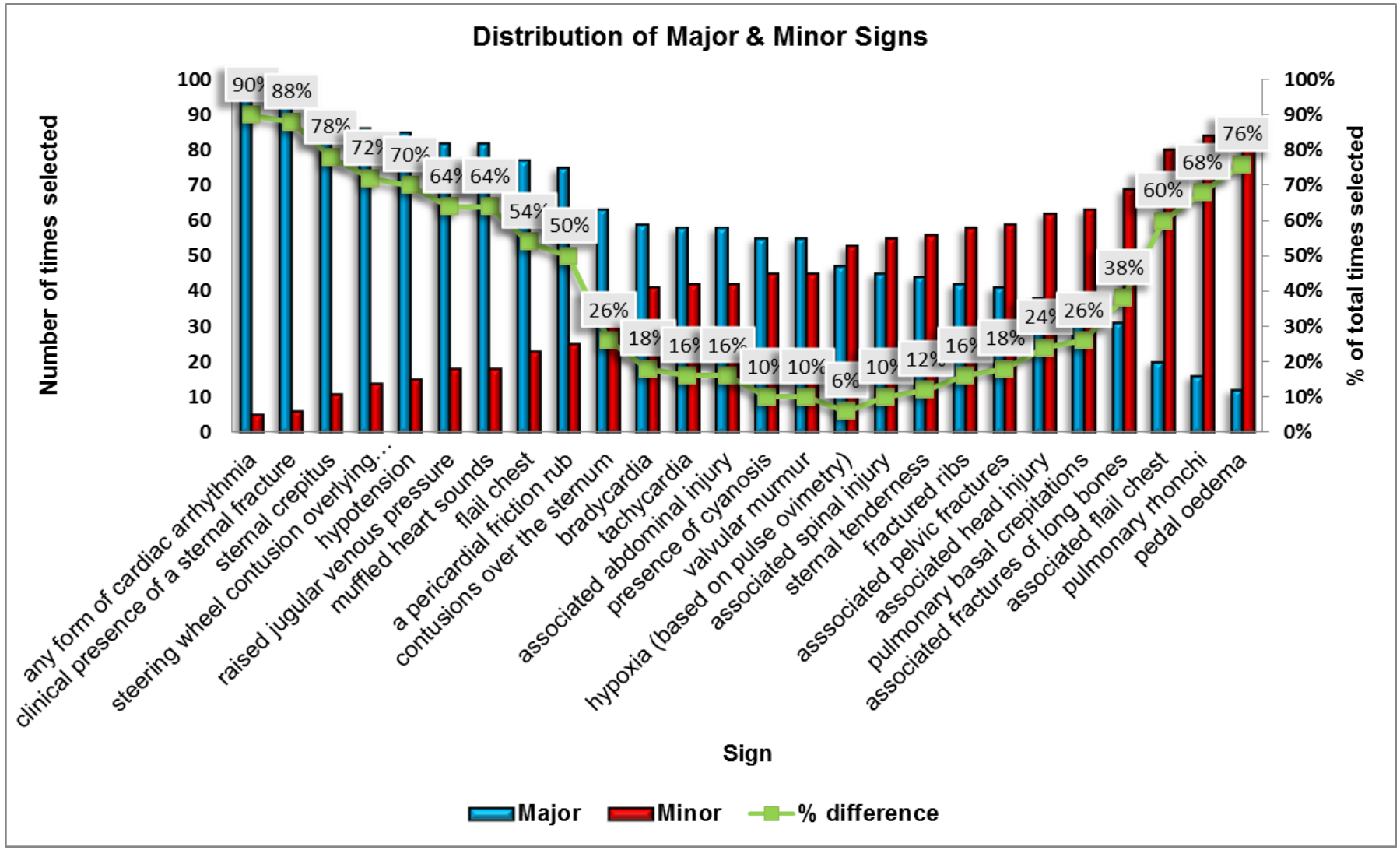
The difference in selection between major and minor signs is expressed as a percentage difference. The narrower the percentage difference the greater the uncertainty as to whether the sign should be a major sign or a minor sign. This lack of consistency has clinical importance in the interpretation of the sign and its relevant significance.

**Figure 16** Distribution of Major and Minor Signs selected (Page 51).

(A major sign was selected 15 times and a minor sign was selected 11 times).

**Figure 17** Percent difference between Major and Minor Signs selected (Page 52).


Distribution of Major & Minor Signs
Number of times selected
Percent of total times selected
Sign
Major
Minor
% difference
any form of cardiac arrhythmia
clinical presence of a sternal fracture
sternal crepitus
steering wheel sternal contusion
hypotension
raised jugular venous pressure
muffled heart sounds
flail chest
a pericardial friction rub
contusions over the sternum
bradycardia
tachycardia
associated abdominal injury
presence of cyanosis
valvular murmur
hypoxia (based on pulse ovimetry)
associated spinal injury
sternal tenderness
fractured ribs
asssociated pelvic fractures
associated head injury
pulmonary basal crepitations
associated fractures of long bones
associated flail chest
pulmonary rhonchi
pedal oedema
90%
88%
78%
72%
70%
64%
64%
54%
50%
26%
18%
16%
16%
10%
10%
6%
10%
12%
16%
18%
24%
26%
38%
60%
68%
76%


Distribution of Major & Minor Signs
Number of times selected
% of total times selected
Sign
Major
Minor
% difference
any form of cardiac arrhythmia
clinical presence of a sternal fracture
sternal crepitus
steering wheel contusion overlying…
hypotension
raised jugular venous pressure
muffled heart sounds
flail chest
a pericardial friction rub
contusions over the sternum
bradycardia
tachycardia
associated abdominal injury
presence of cyanosis
valvular murmur
hypoxia (based on pulse ovimetry)
associated spinal injury
sternal tenderness
fractured ribs
asssociated pelvic fractures
associated head injury
pulmonary basal crepitations
associated fractures of long bones
associated flail chest
pulmonary rhonchi
pedal oedema
90%
88%
78%
72%
70%
64%
64%
54%
50%
26%
18%
16%
16%
10%
10%
6%
10%
12%
16%
18%
24%
26%
38%
60%
68%
76%

### 4.4 Question 10: Special Investigations NORMALLY PERFORMED and what IDEALLY should be performed in the diagnostic assessment of acute cardiac injury following blunt chest trauma.

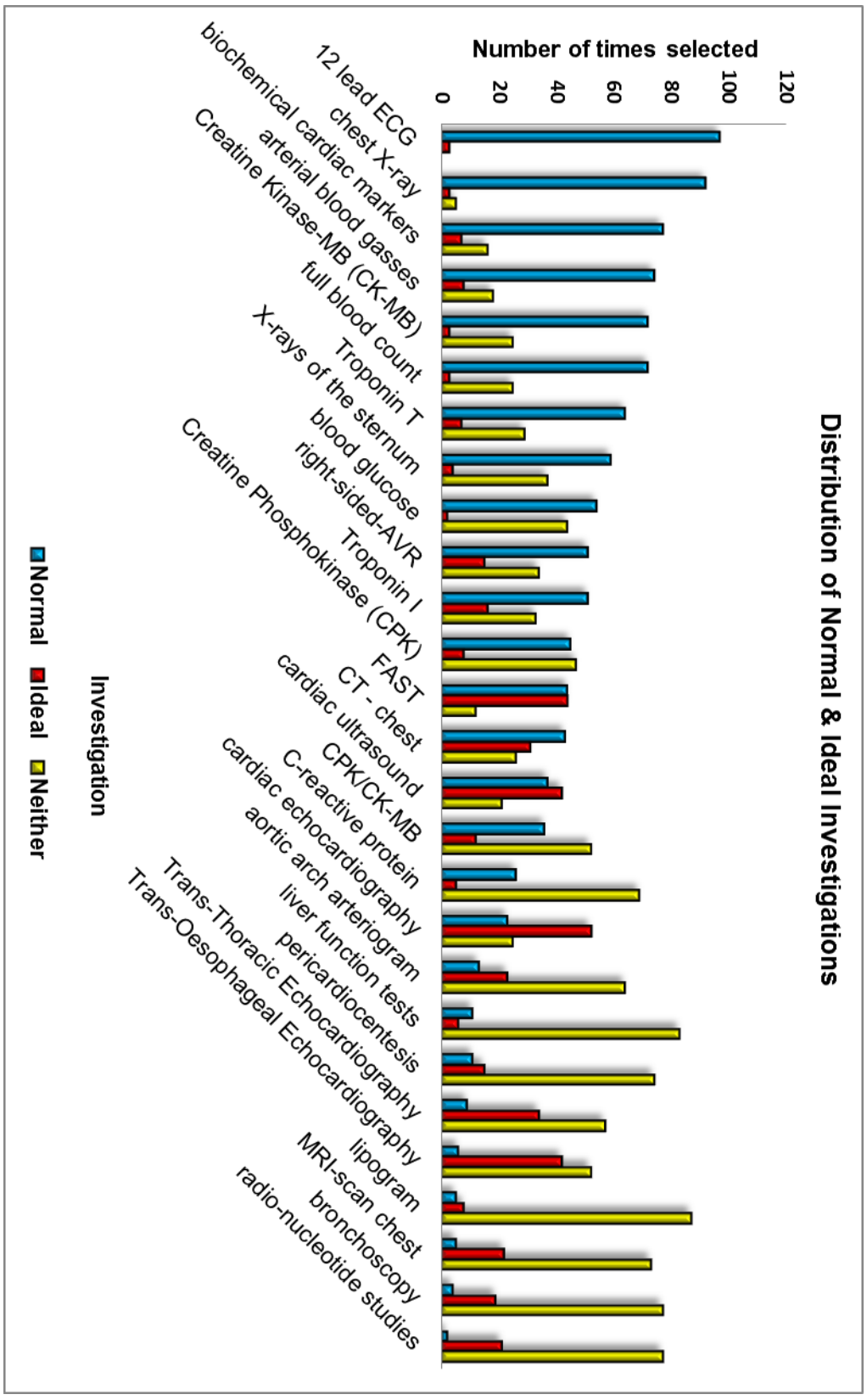
The results showed the distribution of investigations “Normally” performed and those that “Ideally” should be performed. In addition the percentage difference for the normal vs the ideal investigations as well the percentage difference of neither investigation chosen vs normal and ideal investigation.

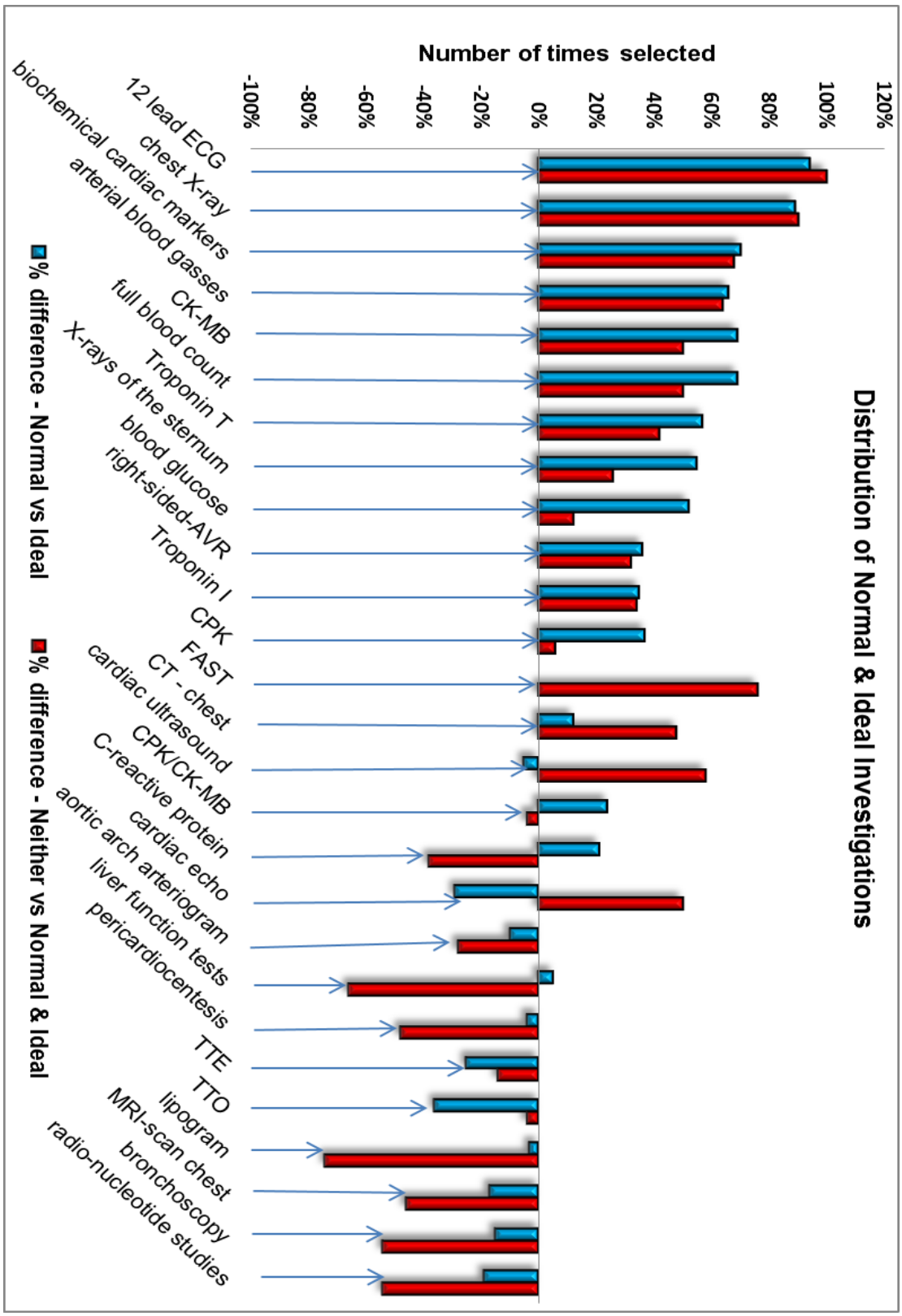
The following two figures illustrate the results:

**Figure 18** Distribution of Normal and Ideal Investigations (page 54).

- The difference in the distribution of Normal vs Ideal investigations and Neither vs Normal plus Ideal investigations performed, expressed as a percentage.

**Figure 19** Percent difference in distribution of Normal vs. Ideal Investigations, and Neither vs Normal plus Ideal Investigations performed (page 55).


Distribution of Normal & Ideal Investigations
Number of times selected
0
20
40
60
80
100
120
12 lead ECG
chest X-ray
biochemical cardiac markers
arterial blood gasses
Creatine Kinase-MB (CK-MB)
full blood count
Troponin T
X-rays of the sternum
blood glucose
right-sided-AVR
Troponin I
Creatine Phosphokinase (CPK)
FAST
CT - chest
cardiac ultrasound
CPK/CK-MB
C-reactive protein
cardiac echocardiography
aortic arch arteriogram
liver function tests
pericardiocentesis
Trans-Thoracic Echocardiography
Trans-Oesophageal Echocardiography
lipogram
MRI-scan chest
bronchoscopy
radio-nucleotide studies
Investigation
Normal
Ideal
Neither


Distribution of Normal & Ideal Investigations
Number of times selected
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
12 lead ECG
chest X-ray
biochemical cardiac markers
arterial blood gasses
CK-MB
full blood count
Troponin T
X-rays of the sternum
blood glucose
right-sided-AVR
Troponin I
CPK
FAST
CT - chest
cardiac ultrasound
CPK/CK-MB
C-reactive protein
cardiac echo
aortic arch arteriogram
liver function tests
pericardiocentesis
TTE
TTO
lipogram
MRI-scan chest
bronchoscopy
radio-nucleotide studies
% difference - Normal vs Ideal
% difference - Neither vs Normal & Ideal

# CHAPTER 5

## 5.0 DISCUSSION

Establishing the diagnosis of BCI by the ED doctor requires a high index of suspicion, clear clinical judgement, application of current diagnostic protocols and prompt and appropriate management for a successful outcome. As with any patient admitted to the ED, obtaining a comprehensive history (including any risk factors – pertaining to the patients' medical history), careful evaluation of the mechanism of injury, a full physical examination and the appropriate special investigations is mandatory.[6, 8, 22, 44, 59, 80, 82]

The majority of patients are asymptomatic. Those that are symptomatic most commonly complain of chest pain, but this can be confounded by the presence of chest wall injuries. More substantial BCI may manifest as shock, which must be distinguished from other causes of hypotension such as a tension pneumothorax, neurogenic and hypovolemic shock. Attempts have been made to identify specific injuries that might be strongly associated with BCI, such as sternal fracture, but no such associations has been demonstrated.[37, 38, 41] Diagnostic tests should be limited to identify those patients who are at risk of developing cardiac complications as a result of BCI.[9, 21] Identifying the patient at risk for adverse events from BCI (including multiple and severe chest wall injuries and unexplained hypotension) and then applying appropriate monitoring and treatment remains the key issue.

Conversely, patients not at risk could potentially be discharged from the ED with appropriate follow-up.[5, 8, 22, 52, 78, 79, 82]

Numerous investigations and various modalities have been employed to establish the diagnosis of BCI including cardiac enzymes, CT-scan, MRI, TTE and TEE and nuclear medicine scans. The initial evaluation includes an admission 12-lead ECG and a troponin assay. Obtaining a chest X-ray (and may detect chest wall injuries such as rib fractures, which are commonly seen in conjunction with BCI) and FAST/eFAST (and other investigations such as arterial blood gasses and FBC) are all appropriate for patients presenting with significant BCT.[5-10] The literature review recommends that an admission 12-lead ECG together with a cardiac troponin assay is sufficient to assess for acute BCI.[8, 9, 20, 22, 32, 45, 82, 84-86]

The ECG has been extensively studied and remains the most commonly recommended tool for the initial diagnosis of BCI. The admission ECG is a valuable screening tool that may detect rhythm and conduction disturbances. However, there is no pathognomonic finding to reliably diagnose BCI. The addition of a troponin I or T assay increases the negative predictive to 100%.[22, 25, 50, 57, 79, 80, 82] The ideal timing for troponin assays is not yet determined and a secondary measurement at 4-6 hours and at 24 hours (there is no consensus on this timing) is necessary to reliably exclude cardiac injury – especially if the troponin concentrations are within the normalreference ranges on admission or shortly after the trauma.

These cardio-specific assays have improved the detection of myocardial injury – particularly in patients without evident signs of cardiac injury.[5-10]

CK, CK-MB and CK/CK-MB ratio should not be performed since they lack specificity and are not useful in predicting complications related to BCI.[20, 22, 25, 30]

The Fast and eFAST investigations are routinely performed in cases of BCT.[84-86]

[5, 8, 22, 52, 78, 79, 82]

Routine TOE or TTE is not useful as a primary screening modality for BCI and should rather be reserved as a diagnostic test for those patients who are haemodynamically unstable and in those patients with a new or persistent arrhythmia and to segmental wall abnormalities or valvular dysfunction.[6, 22, 44, 49, 57, 72, 73, 75, 76, 82]

Cardiac-CT and MRI is reserved for differentiating an acute myocardial infarction from BCI in trauma patients with an abnormal ECG, cardiac enzymes and / or abnormal ECHO. [5-10, 22, 52, 78, 79. 82]

Historically, radio-nucleotide scans have been used for diagnosis of BCI, but none have been sufficiently sensitive or specific to reliably diagnose BCI and their use has been abandoned as they add little value.[79, 80, 81]

Therefore, a consensus of a combination of a normal ECG and cTnI/T at admission rules out the diagnosis of significant BCI and in the absence of any other reasons for hospitalisation, such patients can be safely discharged thus avoiding extensive diagnostic screening.[22, 25, 52, 59, 81, 83, 86,]

Analysis of the responses to the questions asked provided a revelation to the objectives of this research survey.

### 5.1 Demographic Data

The majority of doctors (49%) were aged between 31 years to 40 years of age - which is the international norm for doctors working in EDs. No analysis was done to compare any possible difference in the responses with respect to the various age groups of the participating doctors since this was not an objective.

Sixty percent of the respondents practiced as GPs and the remainder as SEPs. Forty seven percent worked in private EDs, 40% in a public EDs and 13% in both private and public EDs. The majority (77%) of doctors worked full-time.

In the private sector 75% of the doctors worked full-time and the majority (76%) were GPs.

In the public sector 81% of the doctors worked full-time and 52% were GPs and 48% were SEPs. No analysis in the responses were performed as to whether there were any differences between doctors who worked part-time or full-time or whether doctors worked in a private or a public hospital since these were not an ojective. Doctors were practicing as either GPs (60%) or SEPs (40%).

The participating doctors hold either post-graduate qualifications and / or attended courses in emergency medicine. The majority (81%), hold both the ATLS© and ACLS© courses, 33% hold a DIP PEC (SA), 12% hold a FCEM (SA), 10% hold a MPhil (EM) and 8% hold a MSc MED (EM) qualification.

Doctors practicing as a SEP (40%) included those that have a FCEM (SA), MSc MED (EM) or MPhil (SA) qualification. Four doctors (4%) practiced as a SEP with their highest qualification being a DIP PEC (SA). In addition, six doctors (6%) practiced as a SEP with their "other" qualification being an MMED (SA) (three doctors), an MRCP (UK) (two doctor) and an ABEM (USA) (one doctor).

The majority of the respondents (81%) came from the Gauteng and the Western Cape provinces. This may reflect the concentration of hospitals in these two provinces which in turn may reflect the resources available to deal with trauma – both human resources and the availability of EDs.

The research survey was sent to all the available facilities in the various provinces – both private and public hospitals. No analysis were performed to compare the responses from the various provinces as this was not an objective.

The demographic data indicate that the doctors were all working in EDs throughout South Africa and are either GPs (with training in emergency medicine) or SEPs.

### 5.2 Medical History

General enquiry about the patient's age, past medical history and presence of any co-morbid conditions (specifically a history of ischaemic heart disease and cardiac risk factors, including angina, previous myocardial infarction, recent angioplasty, hypertension, diabetes, and hypercholesterolaemia), habits (smoking and alcohol consumption), current medication, illicit drug use and occupation are all important to establish as they contribute to the overall assessment of the injury.

From the literature review it has been established that patients older than 55 years' of age and a past medical history of cardiac disease are at increased risk of complications following BCI.

Medication such as calcium channel blockers or β-blockers and illicit drugs such as cocaine may alter findings on the clinical examination such as affecting the pulse rate. Many RTAs are the result of alcohol consumption or illicit drug use and both of these toxins predisposes the patient to more serious injury and more adverse outcomes.[1-4]

The responses showed that 28% of doctors failed to enquire about alcohol consumption (with GPs asking 16% less than SEPs) and a further 37% did not ask about illicit drug usage (SEPs enquired less than GPs - 26% vs 17%: Figure 10). A further 6% failed to ask about past medical history and another 6% failed to ask about medication history.

This lack of enquiry into alcohol consumption or illicit drug usage should be of concern in not fully evaluating the history of the incident. The rest of the responses between the SEPs and GPs were very similar and showed very small statistical differences.

Additional and significant factors on the medical history that should alert one to the possibility of acute cardiac injury following BCT was the mechanism of injury and includes the force of impact (high velocity impact/estimated speed of the vehicle/ height of the fall/weight of the crushing force) and whether seat belt restraints were worn or not.

In a total of a possible 600 responses (six possible questions times' 100 respondents) 95 possible responses (or 16%) failed to enquire about the mechanism of injury. There were no statistical differences in the responses between SEPs and GPs (Figure 10).

The responses revealed that 46% of respondents failed to ask about the weight of the crushing force, 27% failed to ask about the type of vehicle and 14% failed to ask about the speed of the vehicle involved. In 1%, the wearing of a seat belt was not asked (Figure 10).

Although there are no specific symptoms pertaining to the injury following BCT there are important symptoms that should alert one to the possibility of a significant chest injury. These include chest pain, dyspnoea, tachypnoea and palpitations (Figure 13).

These four symptoms were selected by two thirds (**68%**) of the respondents as the most important symptoms. The distribution of the four symptoms selected (adding up to 100% and evenly weighted at 25% per symptom):

- **Chest pain** (94 times selected or **24%** of total times selected).
- **Dyspnoea** (70 times selected or **18%** of total times selected).
- **Tachypnoea** (69 selected or **17%** of total times selected).
- **Palpitations** (37 times selected or **9%** of total times selected).

Other “important” symptoms most frequently selected (adding up to **29%)**:

- Syncope (32 times selected or **8%** of total times selected).
- Diaphoresis (31 times selected or **8%** of total times selected).
- Haemoptysis (26 times selected or **7%** of total times selected).
- Confusion (23 times selected or **6%** of total times selected).

These results clearly showed a lack of consistency and agreeable consensus on the symptoms that should be considered relevant and important in raising suspicion of significant BCT with only two thirds of respondents selecting these important symptoms.

There were no significant statistical differences in the selection of the most important symptoms between SEPs and GPs, with GPs selecting slightly more of the symptoms indicating a greater awareness (Figure 14).

Few symptoms and signs are specific for BCI and early symptoms of cardiac compromise may be absent or simply masqueraded by the physiological disturbance produced by associated injuries. Significant symptoms on the medical history that raises suspicion of possible acute BCI following BCT include chest pain (the commonest presenting symptom which may or may not be anginal in nature, and it is usually the result of thoracic trauma) and dyspnoea.[9, 10]

Question eight asked for the two most important symptoms alerting one to the possibility of acute cardiac injury.

The maximum percentage times selected could not exceed 50% since a maximum of two symptoms were required for the answer. That is, if a symptom was asked for by all respondents, that symptom would represent 50% of all responses.

The distribution for the selection of these two symptoms (adding up to 100% and evenly weighted at 50% per symptom):

- **Chest pain:** Selected **89** times (or **45%** of a possible choice of two answers).
- **Dyspnoea:** Selected **46** times (or **23%** of a possible choice of two answers).

These two chosen responses add up to **68%** for the selection of the two most important symptoms alerting one to the possibility of BCI.

Other symptoms selected:

- **Palpitations** – selected **38** times (or **19%** incidence as one of the two symptoms).
- This third most chosen symptom is interesting in that it is considered almost as important as dyspnoea (20% vs 23%). This symptom might indicate an arrhythmia which is a rare acute presentation (incidence of less than 10% [7, 8, 9, 14, 23]) and usually may occur only after 24 to 48hrs.[21, 22, 24] The palpitations may have a non-cardiac source such as pain, anxiety, hypoxia, alcohol intoxication, haemorrhage, hypokalaemia, head injury, pulmonary contusion (may be due to pre-existing cardiac disease).[32, 36]

- **Other** – selected **27** times (or **15%** incidence).

  Confusion was selected 9 times, light-headedness 7 times, dizziness 6 times, and nausea and vomiting and weakness twice each.

### 5.3 Physical Examination

Patients at risk for clinically significant BCI following BCT should be identified by the following signs which should be considered as major signs: [9, 14, 27, 28]

- Arrhythmia/s.
- Hypotension.
- New murmur/s.
- Pericardial friction rub or muffled heart sounds with raised jugular venous pressure and narrow pulse pressure indicative of cardiac tamponade.
- Associated chest injuries: [28, 29, 30]
  - Multiple rib fractures, sternal, scapular fractures or flail chest
  - Pulmonary contusion (wheezing, rhonchi, crepitations)
  - Haemo/pneumothorax
  - Major vessel injury such as aortic rupture
- Other: [9, 14, 15, 27, 28, 29, 30]
  - Head injury (incidence of BCI 20% - 73%).
  - Extremity injury (incidence of BCI 20% - 66%).
  - Abdominal solid organ injury (incidence 5% - 43%).
  - Hip and Spinal injury (incidence 10% - 20%).

Signs that should not be considered as a minor sign following BCT: [9, 14, 27, 28, 38, 39]

- Sternal or chest wall tenderness or any instability.
- Abrasions or contusions of the sternum and chest e.g. “seatbelt sign” or the imprint of the steering wheel.

The survey provided a choice of 26 physical signs and the doctors were required to consider each sign as either a major sign or a minor sign that might alert one to the possibility of clinically significant BCI following BCT. The results showed an interesting selection between what were considered either a major sign or a minor sign and also revealed an uncertainty between the two signs.

More major signs (15 signs) than minor signs (11 signs) were selected.

Of the 15 signs selected as major signs, only 11 (or 74%) of those signs were recognised as acceptable major signs and of those signs selected as a major sign, the same “major” sign were considered to be a minor sign by some respondents. (Figures 16 and 17).

The following nine signs were selected preferably as a **major sign vs minor sign** in order of the frequency they were selected and expressed as a percentage difference:

- Any form of cardiac arrhythmia **(95 vs 5)** – (**90%** difference).
- Clinical presence of sternal fracture **(94 vs 6)** – (**88%** difference).
- Sternal crepitus **(89 vs 11)** – (**78%** difference).
- Steering wheel contusion overlying sternum **(86 vs 14)** – (**72%** difference).
- Hypotension **(85 vs 15)** – (**70%** difference).

- Raised jugular venous pressure **(82 vs 18)** – (**64%** difference).
- Muffled heart sounds **(82 vs 18)** – (**64%** difference).
- Flail chest **(77 vs 23)** – (**54%** difference).
- Pericardial friction-rub (**75 vs 25**) – (**50%** difference).

The following eight signs were selected preferably as a **minor sign vs major sign** when they should have been considered as a major sign:

- Pedal oedema **(88 vs 12)** – (**76%** difference).
- Pulmonary rhonchi **(84 vs 16)** – (**74%** difference).
- Abrasions of the skin overlying the sternum **(80 vs 20)** – (**60%** difference).
- Associated fractures of long bones **(69 vs 31)** – (**32%** difference).
- Pulmonary basal crepitation's **(63 vs 37)** – (**25%** difference).
- Associated head injury **(62 vs 38)** – (**24%** difference).
- Associated pelvic fractures **(58 vs 42)** – (**18%** difference).
- Contusion of the skin overlying the sternum (**63 vs 37)** – (**26%** difference).

The following nine signs were selected preferably as a **major sign** rather than a minor sign and there were not a significant difference in whether the sign was a major or a minor one as expressed by the percentage difference, and this reveals inconsistency in regarding the significance of the sign/s presenting.

The greatest difference (or uncertainty) between a major or, a minor sign was for:

- Bradycardia **(59 vs 41)** – (**18%** difference).
- Fractured ribs **(58 vs 42)** - (**18%** difference).
- Sternal tenderness **(56 vs 44)** - (**16%** difference).

- Tachycardia **(58 vs 42)** – (**16%** difference).
- Associated abdominal injury **(58 vs 42)** – (**16%** difference).
- Presence of cyanosis **(55 vs 45)** – (**10%** difference).
- Valvular murmurs (e.g. mitral incompetence) **(55 vs 45)** – (**10%** difference).
- Associated spinal injury **(55 vs 45)** - (**10%** difference).
- Hypoxia (based on pulse oximetry) **(53 vs 47)** - (**6%** difference).

It was evident that not all of the 15 signs selected as a major sign nor all of the 11 signs selected as a minor sign were unanimously selected and showed a large variation.

The clinical presence of a sternal fracture was chosen by 94% of the respondents and as the second most significant major sign selected as an indication of acute cardiac injury following BCT. Five large studies evaluated the relationship of sternal fracture to BCI. These studies concluded that isolated sternal fracture was not a marker of BCI and these patients could be safely discharged if they had a normal ECG and troponin level and was haemodynamically stable and management of patients with a sternal fracture should directed at the management of any associated injuries.[38, 39, 40, 81, 82]

The responses of the doctors doing the survey, without the clinical context, may have considered the worst possible scenario and therefore selected a sternal fracture as a major sign. A sternal fracture may have significance as an indicator of possible myo-pericardial damage when displaced and showing significantly more signs of BCI such as arrhythmias.

Associated injuries occur in 55% - 75% of patients and injuries such as long bone fractures and closed head injuries should always be considered in patients with a sternal fracture. In addition, rib fracture association with a sternal fracture is 49.6% and is more likely to occur in patients older than 55 years of age.[38, 39, 40]

**5.4 Special Investigations.** (Figure 18 and Figure 19).

Question 10 seeks to establish what investigations (a choice of 27 was provided) the doctor would normally perform or would ideally like to perform in the diagnostic assessment of BCI following BCT.

The responses were recorded as those investigations that were **"NORMALLY"** performed, or those that would **"IDEALLY"** like to perform and those that would not perform either (or **"NEITHER"** performed).

The investigations that were selected as "**NORMALLY"** performed:

- 12 lead ECG was performed in **97%** of cases (and ideally in 3%) – this investigation should have been selected in 100% of cases as evidenced by the literature review. [6-11, 14, 20, 21, 23, 25, 30, 31, 32, 42, 43, 45, 82, 84] Those respondents selecting "ideally" presumably were not sure or did not have an ECG machine.
- Chest X-ray was performed in **92%** (ideally in 3% and neither in 5%) – this investigation should be performed in all patients presenting with BCT as part of the normal assessment.[5, 6, 9, 17, 18, 20, 56] It was interesting to note that 5% of respondents would not perform a Chest X-ray following BCT and those selecting "ideally" were not sure or did not have the resource.

- Biochemical cardiac markers were performed in **77%** (ideally in 7% and neither in 16%) – this terminology probably caused some confusion because it was not specific, however 16% responded that they would not do any cardiac markers.
- Arterial blood gases were performed in **74%** (ideally in 8% and neither in 18%) – although this investigation could "ideally" be performed in a patient presenting with BCT it lacks specificity and it is not normally performed in the diagnostic assessment of acute BCI.[17]
- CK-MB was performed in **72%** (ideally in 3% and neither in 25%); CK in **45%** (ideally in 8% and neither in 47%) and CK/CK-MB ratio in **36%** (ideally in 12% and neither in 52%) - these investigations are obsolete and should not be performed. [6, 8, 9, 11, 18, 28, 29, 30, 32, 50] It was interesting to note that more than 50% would normally and ideally would perform a CK or CK/CK-MB and 75% would normally and ideally perform a CK-MB analysis. The appropriate responses should have been 100% neither normally nor ideally performed for these cardiac enzymes.
- FBC performed in in **72%** (ideally in 3% and neither in 25%) – was not normally performed to assess acute BCI and should rather have been selected as ideally (as part of the normal assessment of a trauma patient).

- Troponin T was performed in **64%** (ideally in 7 and neither in 29%) and Troponin I in **51%** (ideally in 16% and neither in 33%). The appropriate responses should have been 100% as normally performed. It was interesting to note how many respondents would not normally perform this investigation and how many considered a difference in their selection as a cardiac biomarker. There is no current difference in selecting either cTnI or cTnT as the marker of choice.[15, 22, 23, 25, 29, 32, 33, 48, 52, 54- 59, 81, 82, 83, 86,
- X-rays of the sternum was performed in **54%** (ideally in 9% and neither in 37%) – this investigation is not normally performed in the diagnostic assessment of BCI as there was no correlation between sternal fracture and BCI.[38, 39, 40, 82]
- Blood glucose was performed in **54%** (ideally in 2% and neither in 44%) – this investigation has no value in the diagnostic assessment, yet it was selected by over half of the respondents.
- A right-sided AVR ECG lead was performed in **51%** (ideally in 15% and neither in 34%) Use of a right-sided precordial lead does not aid in the diagnosis of BCI.[6, 9]
- FAST was performed in **44%** (ideally in 44% and neither in 12%) – this investigation has become a “normal” in the assessment of BCI and BCT. If not selected as a normal investigation by 100% of the respondents it should have been selected as “ideally (given the resources and skills).[82, 83]

- CT-Chest was performed in **43%** (ideally in 31% and neither in 26%). This investigation is not normally performed in the diagnostic assessment of BCI following BCT. [76, 77, 82]

The following questions were preferentially selected as "**IDEALLY"** would be performed:

- Cardiac ultrasound was performed in **42%** (normally in 37% and neither in 21%) and cardiac ECHO in **52%** (normally in 23% and neither in 25%).[70] It was interesting to note that there was no difference between cardiac ultrasound or cardiac ECHO yet they differed in selection (particularly those who selected as "normally" investigated). In addition, TOE and TEE was preferentially selected as "neither" would be performed. It implies a misunderstanding of the terminology and the application of investigations.

The following questions were preferentially selected as "**NEITHER"** would be performed but was selected as normally and ideally investigated:

- TTE was performed in **57%** (normally in 9% and ideally in 34%) and TOE in **52%** (normally in 6% and ideally in 42%). These investigations have no role in the initial investigations to diagnose BCI following BCT. [6, 22, 28, 55, 70, 72, 73, 74, 75, and 76]
- MRI-scan of Chest was performed in **73%** (normally in 5% and ideally in 22%). This investigation should not be performed in the diagnosis of BCI. [76, 77, 82]

- Radionucleotide studies performed in **77%** (normally in 2% and ideally in 21%). These investigations have been shown to be of no value in the diagnostic assessment of BCI.[76, 77, 78]
- C-reactive protein (CRP) performed in **69%** (normally in 26% and ideally in 5%).
- Liver function tests performed in **83%** (normally in 11% and ideally in 6%).
- Pericardiocentesis performed in **74%** (normally in 11% and ideally in 15%).
- Aortic Arch Arteriogram performed in **57%** (normally in 9% and ideally in 34%).
- Bronchoscopy performed in**77%** (normally in 4% and ideally in 19%).

The above four investigations have no value in the diagnostic assessment of BCI and should not have been selected. In some responses the selection to ideally perform the investigations is unacceptable and inappropriate.

The overall responses were varied and not consensus driven and with many investigations outdated, inappropriate, inaccurate, and unnecessary.

The general implication is that many unnecessary and costly investigations are performed and in many instances these outdated and non-specific investigations make accurate interpretation of results inaccurate, confusing and inappropriate.

It becomes crucial then to determine exactly what diagnostic studies are required to safely rule out BCI and to allow for safe discharge home or to a non-monitored setting. The decision to screen (and choice of diagnostic testing) is doctor dependent because there are no standard criteria.

### 5.5 Strength of this research survey

This research study is the first of its kind to be done in South Africa and sets out to review what methods are currently practiced to diagnose acute BCI following BCT by doctors working in EDs. It is evident that detection of BCI based on the current literature appropriateness remains challenging and it appears that there are still no utilisation of consistent diagnostic criteria for BCI by the respondents. The responses to the survey revealed the doctors interpretation and confirmed the uncertainty and confusion in establishing the diagnosis. A significant variance and a lack of consistency to the questions asked and in particular, diagnostic testing, many of which were inappropriate, unnecessary and not based on consensus driven and evidence based research was revealed.

### 5.6 Limitations of this research survey

Although this research was carefully prepared and has achieved its aims and objectives there are some limitations and weaknesses. The questions on the demographic data could have been limited (questions 1-4) as it did not provide any value (other than indicate the age of the participating doctor, whether working in the private or public sector and whether full-time or part-time) to the research question which focused on a review of how doctors diagnose BCI following BCT.

An analysis to ascertain any differences to the responses between those doctors that worked part-time or full-time or whether they worked in private or public hospitals or in which province they worked could have been done – but these were not the aims nor objectives of this research study.

Several other limitations, difficulties and problems encountered need to be acknowledged.

- Difficulties in obtaining a comprehensive and accurate data base for doctors working in EDs throughout South Africa.
- Difficulties in obtaining e-mail addresses and contact details for the doctors working in EDs since there is no e-mail directory of doctors working in emergency medicine (framing problem).
- Incorrect e-mail addresses, unknown e-mail addresses: resulting in 88 electronically mailed surveys to be returned.
- The survey not reaching all the intended participants.
- Difficulties in getting information from nurses on duty working in EDs in public hospitals. Difficulties in getting telephonically through to public hospitals and then having the request to be transferred to the Emergency Department being lost, misplaced or put-on-hold.
- Coverage error. A shortcoming of web-based surveys.
- Non-response. Online survey response rates are generally low and also vary extremely – from less than 1% in enterprise surveys with e-mail invitations to almost 100% in specific membership surveys.

Non-response bias was a significant concern and particularly salient for web-based research. An acceptible response rate would be 20%.

- Low response rates which occurs with web-based surveys:

  Psychological reasons include:

  - Doctors may have forgotten about it.
  - Doctors may be too busy to want to take the time to fill out the questionnaire.
  - Doctors may find surveys a disruption to their personal lives.
  - Concerns with security, data integrity, technical problems and other reasons of unwillingness or inability to participate in the survey.
  - Perception that the survey is too long.
  - Perception as junk mail.
  - Impersonal.

  Mechanical reasons may include:

  - Lack of internet access – technology reliance.
  - Respondents lack online experience or computer literacy and issues with compatible hardware and software.

- Questionnaire design. Measurement errors can arise due to the survey mode itself. Closed-ended questions have the disadvantage of respondents tending to confirm their answers to the choices offered as a provoked response.

- Possible methodological limitations and sampling error include sample size, measures used to collect and analyse the data (although this was statistically determined). This may be reduced by increasing the sample size however the survey bias may not be affected.

### 5.7 Source of bias

The survey sample size of 100 doctors may not accurately represent the population of doctors working in EDs. The number of respondents who chose to respond to the survey question may be different than those who chose not to respond thus creating bias.

This may be due to:

- Unrepresentative samples: Under-coverage (There may be public hospitals in some of the provinces that are busy, seeing many cases of BCT, yet was unreachable with the electronic format of the research), non-response bias (unwilling or unable to participate in the survey) and voluntary response bias.
- Measurement error: Leading closed-ended worded questions may have favoured a response with respondents who have a propensity to agree more positively and with bias inherent in these questions. The “ideal” answer being provided rather than a “realistic” one which may be bias.
- Sample bias: the online survey is “self-selected.” Doctors receiving the online survey and invited to participate makes themselves “self-selected”- they decide to participate and their participation may / may

not provide a representative sample.

An attempt to direct the questions directly at the participating doctor – “what do you do?” was made however, respondents may answer what they think is expected from them and not what they actually do which may lead to bias error. There was bias in question 10 where the question could have been phrased: – “what special investigations would you normally perform in the **initial** diagnostic assessment of acute BCI following BCT” in the acute setting?”

# CHAPTER 6

## 6.0 CONCLUSION

BCI injury remains a difficult diagnosis for the emergency physician and the diagnosis of clinically significant acute BCI is challenging and remains elusive with the reported incidence, depending on the criteria used for diagnosis, ranging from 7% - 76% in those patients presenting with BCT.[4, 8, 9] BCI injury may occur in patients after sustaining non-penetrating trauma to the chest and ranges from inconsequential to catastrophic and can affect any or all areas of the heart and it should be suspected in all multi-trauma patients presenting to the ED.[3, 4, 5] It is usually sustained in rapid deceleration injuries with a direct blow to the chest and encompasses a wide spectrum of injury with varied severity and clinical presentation and its recognition is crucial as it may cause life-threatening arrhythmias or heart failure. The consequence of BCI injury is dependent upon the nature and the extent of the injury and may vary from asymptomatic electrical conduction abnormalities with no consequence to symptomatic and structural damage and sudden death.[9, 17]

To date, no single test is able to rule out BCI and there is no “gold-standard” investigation or set of signs and symptoms that are diagnostic of cardiac injury and a high index of suspicion for possible cardiac injury should be considered in all patients sustaining BCT.[17, 22]

The challenge remains to identify those patients with clinically significant BCI whilst limiting costly and unnecessary work-up for patients with low risk of haemodynamic instability.

It becomes crucial then to determine exactly what investigations are required to safely rule out BCI and to allow for safe discharge home or to a non-monitored setting. The decision to screen (and choice of diagnostic testing) is doctor dependent because there are no standard criteria. Attempts have been made to identify specific injuries that might be strongly associated with BCI, such as sternal fracture, but no such associations has been demonstrated.

The large variation in incidence and lack of agreement between researchers as to the exact definition of BCI make recommendations for the ED doctor difficult because of the lack of an ideal test. This makes the diagnosis nebulous and with variable outcomes, depending on the definition.[4, 8-11]

The significance of the findings based on the responses suggest that the effectiveness in making the diagnosis is unknown. It does appear that the assessment of the patient to rule out BCI remains a challenge and the reliability of their current practice to detect BCI is unpredictable and this would warrant a further study. The majority of these doctors are not adhering to up-to-date consensus driven and evidenced based practice. The conclusion drawn can only be that we are not effective, (clinically) and by implication we are costly, in making the diagnosis of BCI and confusion still exists in the appropriate methods of investigation.

## 6.1 Recommendations (APPENDIX F).

The recommendations in the literature includes a 24-hour period of observation in a monitored setting and ECG monitoring in all patients suspected of BCI who are haemodynamically stable but have either a normal or an abnormal admission ECG but are older than 55 years of age or a history of cardiac disease since these patients may have delayed presentations of cardiac injury. Conversely, patients who are haemodynamically stable, who are less than 55 years of age, with no history of cardiac disease, and who do not require surgery or observation for any other injuries can have a diagnosis of cardiac injury excluded if there is a normal admission ECG and troponin assay and require no further intervention and can be safely sent home.[5, 6, 8, 21, 22, 25, 44, 59, 80, 82]

It also appears that there was not much difference in the responses between a specialist emergency physician and a general practitioner practicing emergency medicine.

Diagnosing acute BCI following BCT remains a significant challenge because of non-specific signs and symptoms and lack of an ideal diagnostic tool**.** [3-9]

This research has revealed the inconsistencies and confusion in the current practice to diagnose BCI following BCT among doctors who are either SEP or GPs (with several post graduate courses/qualifications in emergency medicine) working in EDs.

A blunt cardiac injury protocol as adopted by The Eastern Association for the Surgery of Trauma.[22, 82]

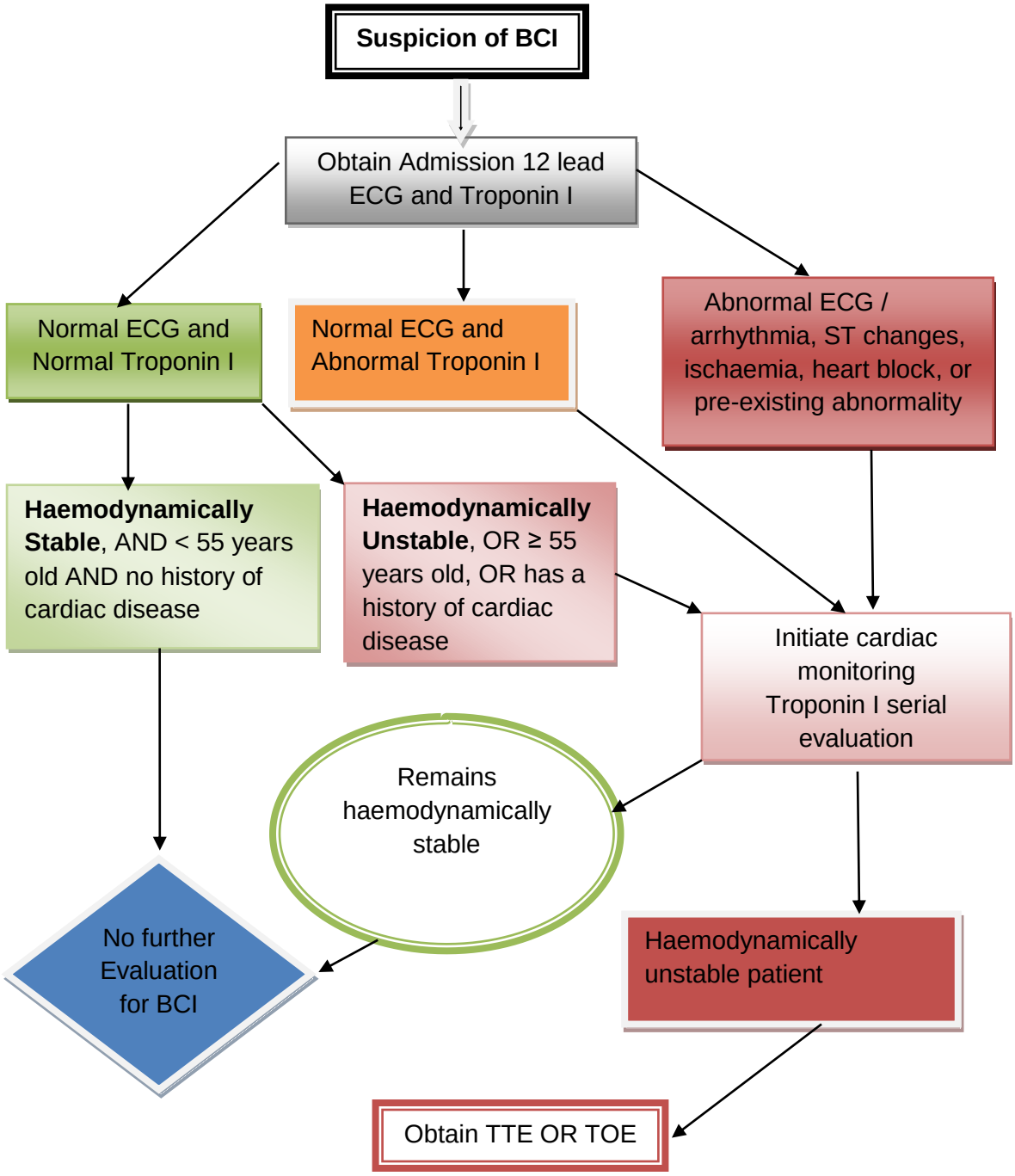



**Figure 20** Algorithm for the evaluation of patients suspected of having BCI

A standard approach to establish whether the heart has been injured or not needs to be established. This should take the form of an algorithm on a wall chart (as presented by the EAST: Figure 20) that is easily accessed in the ED. Further teaching and education on the subject is also suggested. These measures will negate unnecessary and costly investigations and hospital admissions.

A further study could include an open-ended questionnaire thus providing the respondent an unbiased, unprompted response which may be a true reflection of what is practiced. Question 10 should be rephrased to include “what **initial** investigation/s should be performed to rule out BCI?” The relevance of other injuries and association with cardiac injury could be tested and not only limit BCI to isolated BCT.

Further research should attempt to address the limitations present in this study by incorporating the information generated by this study.

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## APPENDICES

## Appendix A: Ethics approval

**.UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG**

Division of the Deputy Registrar (Research)

**HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)**
R14/49 Dr Giovanni FM Afeltra

| | |
|---|---|
| **CLEARANCE CERTIFICATE** | M10M101117 |
| **PROJECT** | To Review How Doctors on Duty in Emergency Departments in South Africa Diagnose Acute Cardiac Injury following Blunt Chest Trauma |
| **INVESTIGATORS** | Dr Giovanni FM Afeltra |
| **DEPARTMENT** | Division of Emergency Medicine |
| **DATE CONSIDERED** | 26/11/2010 |
| **DECISION OF THE COMMITTEE*** | Approved unconditionally |

**Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.**

**DATE** 26/11/20101 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof Efraim Kramer

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**DECLARATION OF INVESTIGATOR(S)**

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

## Appendix B: Letter of introduction to doctors

Dear Colleague,

My name is Dr Giovanni FM Afeltra registered as a student in the Division of Emergency Medicine of the Faculty of Health Sciences at the University of the Witwatersrand. As part fulfilment for the degree of Master of Science in Medicine (Emergency Medicine), I am undertaking a research survey to review how you establish the diagnosis of acute cardiac injury following blunt chest trauma in patients presenting to your emergency department. Prof. Efraim Kramer is my supervisor.

The title of my Research Survey is:

**"Diagnosis of acute cardiac injury after blunt chest trauma presenting to doctors working in Emergency departments in South Africa."**

Cardiac injury following blunt chest trauma presents clinically as a spectrum of varying severity and the sequelae from these injuries range from benign to catastrophic. Lack of a clinical gold standard makes it difficult to interpret the literature. A heightened level of suspicion, based on the history of the mechanism and nature of the force of the trauma, the clinical signs and symptoms that may alert one to the possibility of acute cardiac injury together with the appropriate investigations, should result in early identification and reliable detection.

However, since there are no absolute diagnostic criteria to assess cardiac injury with absolute certainty accurate assessment remains challenging.

The intention of performing this survey is to establish what exactly you do in your emergency department given your available resources and the situation of a patient presenting with blunt chest trauma – how do you diagnose an acute cardiac injury?

Please would you complete the attached questionnaire by marking the relevant boxes at www.surveymonkey.com. By linking onto the website you are granting consent for your answers to be included in the study and your answers are completely confidential.

Link: **http://www.surveymonkey.com/s/VYHN2L6**

Ethics approval, namely Clearance Certificate: M10M101117 for this research project has been obtained from the University of the Witwatersrand, Faculty of Health Sciences Human Ethics Research Committee.

If there are any queries that you have, please do not hesitate to contact me at: giovanni.afeltra@wits.ac.za for further clarification.

Thank you kindly for your time.

Giovanni FM Afeltra

Student No: 7557073

## Appendix C: The online survey

**1. Please indicate if you have a postgraduate emergency medicine qualification or attended any of the following courses:**

- ☐ FCEM(SA)
- ☐ MSc MED(EM)
- ☐ MPhil(EM)
- ☐ DIP PEC(SA)
- ☐ ATLS
- ☐ ACLS
- ☐ PALS/APLS
- ☐ AIME
- ☐ Other (please specify)

**2. Please indicate your age:**

- < 30 years old
- 31 - 40 years old
- 41 - 50 years old
- 51 - 60 years old
- > 60 years old

**3. Please indicate your place of work and whether you are working full-time at one Emergency Department and part-time at another Emergency Department - or you may only work at one Emergency Department. Please mark those items that are personally relevant to yourself:**

| | Yes | No |
|---|---|---|
| Private Hospital Emergency Department | | |
| Public Hospital Emergency Department | | |
| Full-time | | |

| | | |
|---|---|---|
| Part-time | | |
| Specialist Emergency Physician | | |
| General Practitioner | | |

**4. Please indicate the Province/s in which you are working:**

- [ ] Gauteng
- [ ] Western Cape
- [ ] Eastern Cape
- [ ] Northern Cape
- [ ] North West
- [ ] Kwazulu Natal
- [ ] Free State
- [ ] Mpumalanga
- [ ] Limpopo

**5. Which of the following do you enquire about when obtaining a medical history from a patient presenting with blunt chest trauma in your emergency department?**

- [ ] Age of patient
- [ ] Gender of Patient
- [ ] Past medical history - including chronic diseases such hypertension and diabetes
- [ ] Medication history
- [ ] Smoking history
- [ ] Illicit drug history
- [ ] Alcohol intake history
- [ ] Occupation

**6. Which of the following questions do you ask the patient when you suspect acute cardiac injury after sustaining blunt chest trauma?**

- ☐ Type of vehicle driven
- ☐ Estimated speed of the vehicle
- ☐ Mechanism of injury/force of impact

  (i.e. whether a high impact or low impact force was applied to the chest)
- ☐ Whether seat belt restraints were worn
- ☐ Height of the fall if involved in a fall
- ☐ Weight of the crushing force

**7. Which of the following do you regard as the FOUR most important symptoms following blunt chest trauma?**

- ☐ Chest pain
- ☐ Tachypnoea
- ☐ Wheezing
- ☐ Coughing

- [ ] Palpitations
- [ ] Haemoptysis
- [ ] Light-headedness
- [ ] Diarrhoea
- [ ] Dyspnoea
- [ ] Diaphoresis
- [ ] Confusion
- [ ] Syncope

**8. Which of the following TWO symptoms would alert you to the possibility of acute cardiac injury following blunt chest trauma?**

- [ ] Chest pain
- [ ] Dizziness
- [ ] Light-headedness
- [ ] Coughing

- [ ] Nausea and vomiting
- [ ] Palpitations
- [ ] Confusion
- [ ] Weakness
- [ ] Dyspnoea

**9. Which do you regard as a MINOR or MAJOR sign on examination of a patient presenting with blunt chest trauma that would indicate the possibility of acute cardiac injury?**

| | MINOR | MAJOR |
|---|---|---|
| Abrasions of the skin overlying the sternum | | |
| Contusions of the skin overlying the sternum | | |
| Steering wheel contusion overlying the sternum | | |
| Sternal tenderness | | |

| | | |
|---|---|---|
| Sternal crepitus | | |
| Clinical presence of a sternal fracture | | |
| Tachycardia | | |
| Bradycardia | | |
| Hypotension | | |
| Any form of cardiac arrhythmia | | |
| Hypoxia (based on pulse oximetry) | | |
| Presence of cyanosis | | |
| Raised jugular venous pulsation | | |
| Muffled heart sounds | | |
| A pericardial friction rub | | |
| Valvular murmurs (e.g. mitral incompetence) | | |

| | | |
|---|---|---|
| Pedal oedema | | |
| Pulmonary basal crepitation’s | | |
| Fractured ribs | | |
| Flail chest | | |
| Pulmonary rhonchi | | |
| Associated head injury | | |
| Associated abdominal injury | | |
| Associated pelvic fractures | | |
| Associated spinal injury | | |
| Associated fractures of long bones | | |

**10. What Special Investigations do you NORMALLY PERFORM in the diagnostic assessment of acute cardiac injury following blunt chest trauma?**

**What IDEALLY would you like to perform?**

| | NORMALLY PERFORM in your ED | IDEALLY WOULD PERFORM - given the resources |
|---|---|---|
| 12 lead electrocardiogram (ECG) | ☐ | ☐ |
| A right-sided AVR ECG lead | ☐ | ☐ |
| Biochemical cardiac markers | ☐ | ☐ |
| Troponin I | ☐ | ☐ |
| Troponin T | ☐ | ☐ |
| Creatine kinase-MB (CK-MB) | ☐ | ☐ |
| Creatine-phosphokinase (CPK) | ☐ | ☐ |
| CPK/CK-MB ratio | ☐ | ☐ |
| C-reactive protein | ☐ | ☐ |

| | | |
|---|---|---|
| Full blood count | ☐ | ☐ |
| Lipogram | ☐ | ☐ |
| Liver function tests | ☐ | ☐ |
| Arterial blood gasses | ☐ | ☐ |
| Blood glucose | ☐ | ☐ |
| Pericardiocentesis | ☐ | ☐ |
| Chest X-ray | ☐ | ☐ |
| X-rays of the sternum | ☐ | ☐ |
| Cardiac Ultrasound | ☐ | ☐ |
| Cardiac Echocardiography | ☐ | ☐ |
| Focused Assessment with Sonography in Trauma (FAST) | ☐ | ☐ |
| Bronchoscopy | ☐ | ☐ |

| | | |
|---|---|---|
| Aortic Arch Arteriogram | ☐ | ☐ |
| Trans-thoracic Echocardiography (TTE) | ☐ | ☐ |
| Trans-oesophageal Echocardiography (TOE) | ☐ | ☐ |
| CAT-scan of the chest | ☐ | ☐ |
| MRI-scan of the chest | ☐ | ☐ |
| Radio-nucleotide studies | ☐ | ☐ |

## Appendix D: Troponins

**Table i** Conditions in which troponin levels may be elevated: [53, 59, 60]

**Cardiac Causes:**

- Trauma (e.g. Cardiac contusion, defibrillation, cardioversion, ablation, pacing, cardiac surgery)
- Ischaemic heart disease
- Congestive cardiac failure (acute or chronic)
- Inflammatory disease (e.g. myocarditis, pericarditis)
- Hypertension (e.g. pre-eclampsia of pregnancy
- Hypotension (often with an arrhythmia)
- Severe tachycardia (e.g. supraventricular tachycardia)
- Aortic valve disease and hypertrophic obstructive cardiomyopathy
- Aortic dissection
- Coronary vasospasm
- Rhabdomyolysis with cardiac injury
- Transplant-related vasculopathy

**Non-cardiac causes:**

- Haemorrhage (e.g. severe gastrointestinal bleeding)
- Renal failure

- Severe asthma
- Hypothyroidism
- Critical illness (e.g. diabetes, respiratory failure, haemolytic-uraemic syndrome)
- Sepsis
- Strenuous endurance exercise (marathons, triathalons)
- Pulmonary embolism (with severe pulmonary hypertension)
- Burns (especially if > 30% total body surface area involvement)
- Drug toxicity (e.g. cocaine, Herceptin, 5-fluorouracil, cisplatin, snake venom, centipede and jellyfish venom)
- Poisoning (carbon monoxide, cyanide)
- Infiltrative disease (e.g. amyloidosis, sarcoidosis,, scleroderma, haemochromatosis)
- Acute neurologic diseases (e.g. cerebrovascular accident, generalised seizures, subarachnoid haemorrhage, intracranial haemorrhage)

**Table ii** Cardiac Troponins.[48, 61, 62, 63, 64, 65, 66, 67, 68]

Troponin release:

- Troponins are considered leakage proteins.
- Damage to cardiac myocytes resulting in loss of membrane integrity causes release of cTn into the circulation.
- After acute cardiac injury the cytosolic pool is released resulting in an early rise blood levels.
- This is followed by a slower release of structurally bound troponin that results in a sustained elevation.
- Elevated cTn levels indicate myocardial damage but do not provide any information regarding its cause.
- The peak levels of cTnI allow estimation of arrhythmia and left ventricular dysfunction in trauma patients with myocardial contusion.
- The arrhythmogenic effect of myocardial contusion is linked to the energy transmitted during impact in contusion trauma.
- Levels of cTnI < 1.05 µg/L in asymptomatic patients at admission and within 6 hours after admission rule out myocardial injury.
- Levels > 1.05 µg/l mandates further cardiologic work-up for the detection and management of myocardial injury and include echocardiography.
- Elevated cardiac enzymes followed by cardiac complications lead to increased morbidity and mortality of a patient.

## Appendix E: eFAST [11, 44, 47, 69, 77]

The two dimensional imaging modality (M-mode and Doppler) provides direct visualisation of the cardiac structures and ventricular function. It is used to assess the presence of any cardiac injury by diagnosing changes in:

- Functional abnormalities - segmental and wall motion abnormalities hypokinesia, abnormal septal motion, and tricuspid regurgitation).
- Cardiac structural abnormalities
    - Valvular function
    - Any shunting of blood
    - Cardiac chamber size (right ventricular dilation)
- Presence of intracardiac thrombosis
- Presence of cardiac tamponade (pericardial effusion)
- Assessment of left ventricular function (ejection fraction estimation).

Indications:

- Haemodynamically unstable patient (especially if unexplained)
- Clinically significant injuries
- Cardiac complications
    - Abnormal ECG with arrhythmias
    - Heart failure
- Non-cardiac injuries (aortic rupture, pleural effusion)

**Appendix F: The latest (2012) recommended guidelines as published by Eastern Association for the Surgery of Trauma (EAST).** [82]

**Level 1**

1. An admission ECG should be performed on all patients in whom BCI is suspected.

**Level 2**

1. If the admission ECG reveals a new abnormality (arrhythmia, ST changes, ischemia, heart block and unexplained ST changes), the patient should be admitted for continuous ECG monitoring. For patients with pre-existing abnormalities, comparison should be made to a previous ECG to determine need for monitoring.
2. In patients with a normal ECG result and normal cTn I level, BCI is ruled out. The optimal timing of these measurements, however, has yet to be determined. Conversely, patients with normal ECG results but elevated troponin I level should be admitted to a monitored setting.
3. For patients with hemodynamic instability or persistent new arrhythmia, an ECHO should be obtained. If an optimal TTE cannot be performed, the patient should have a TOE.
4. The presence of a sternal fracture alone does not predict the presence of BCI and thus should not prompt monitoring in the setting of normal ECG result and cTn I level.

5. CK with isoenzyme analysis should not be performed because it is not useful in predicting which patients have or will have complications related to BCI.
6. Nuclear medicine studies add little when compared with ECHO and should not be routinely performed.

**Level 3**

1. Elderly patients with known cardiac disease, unstable patients, and those with an abnormal admission ECG result can safely undergo surgery provided that they are appropriately monitored.
2. cTn I should be measured routinely for patients with suspected BCI; if elevated, patients should be admitted to a monitored setting and cTn I should be followed up serially, although the optimal timing is unknown.
3. CT or MRI can be used to help differentiate acute myocardial infarction from BCI in trauma patients with abnormal ECG result, cardiac enzymes, and/or abnormal ECHO to determine need for cardiac catheterization and/or anticoagulation.

## Appendix G: Grading of Cardiac Injury (AHA- AAST Injury Scale).[82]

| | |
|---|---|
| I | Blunt cardiac injury with minor ECG abnormality (nonspecific ST or T wave changes, premature atrial or ventricular contraction or persistent sinus tachycardia) |
| | Blunt or penetrating pericardial wound without cardiac injury, cardiac tamponade or cardiac herniation |
| II | Blunt cardiac injury with heart block or ischaemic changes without cardiac failure Cardiac tamponade or tangential myocardial injury. |
| III | ECG: sustained or multifocal ventricular contractions<br>Blunt cardiac injury with sustained or multifocal ventricular contractions |
| | Blunt or penetrating cardiac injury with septal rupture, pulmonary or tricuspid incompetence, papillary muscle dysfunction or distal coronary artery occlusion without cardiac failure. |
| | Blunt pericardial laceration with cardiac herniation. |
| | Blunt cardiac injury with cardiac failure. |
| IV | Blunt or penetrating cardiac injury with septal rupture, pulmonary or tricuspid incompetence, papillary muscle dysfunction or distal coronary artery occlusion producing cardiac failure. |
| | Blunt or penetrating cardiac injury with aortic or mitral incompetence. |
| | Blunt or penetrating cardiac injury of the right ventricle, right or left atrium. |
| V | Blunt or penetrating cardiac injury with proximal coronary artery occlusion. |
| | Blunt or penetrating injury with left ventricular perforation. |
| | Stellate injuries < 50% tissue loss of the right ventricle, right or left atrium |
| VI | Blunt avulsion of the heart. Blunt or penetrating.<br>Multiple piercings on one or two cavities. |