Using the stress electrocardiograph (ECG) exercise tolerance test (ETT) in an emergency department (ED) to assess low-risk patients with suspected acute coronary syndrome (ACS)

by

Student: Hendrik Matthys Siglé

SGLHEN001

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN

In fulfilment of the requirements for Part III of the degree

Master of Philosophy (Emergency Medicine)

Faculty of Health Sciences

UNIVERSITY OF CAPE TOWN

Date of submission: 30/10/2011

Supervisor [s]: Prof Scott Millar, Cardiology department, University Cape Town

DECLARATION

I, Hendrik Matthys Siglé, declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or in any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature: Signed by candidate.....

Date: .....

ACKNOWLEDGMENT

I would like to acknowledge, in no particular order of importance:

- Prof Scott Millar and Dr Stevan Bruijns, for their guidance and assistance with the dissertation;
- Dr Robert Scott, for doing most of the exercise stress testing, and for alerting me to the possibility of using the database for my dissertation;
- Dr Peter Thompson, for his help and guidance and for making available the administrative support necessary for the dissertation;
- Mrs Sue Davey, for her administrative support;
- the clinical technologists of Medical Measurements of the Rockhampton Base Hospital; and
- the doctors of the resident medical staff of the Hospital who helped with auditing the charts; and
- Mr Clinton Hasses for his unending support and encouragement.

CONTENTS

LIST OF TABLES AND FIGURES

LIST OF ABBREVIATIONS

ACS	acute coronary syndrome
AMI	acute myocardial infarction
β-blocker	beta-blocker
CA	coronary angiography
CAD	coronary artery disease
cAMP	cyclic adenosine monophosphate
CCU	coronary care unit
CK	creatinin kinase
CK-MB	creatinin kinase MB fraction
CM	clinical measurement
CPU	chest pain unit
CVD	cardiovascular disease
CXR	chest X-ray
ECG	electrocardiograph
ED	emergency department
EDIS	Emergency Department Information System
EDOU	emergency department observation unit
ETT	exercise tolerance test
GFR	glomerular filtration rate
GRACE	Global Registry of Acute Coronary Events
GTN	glycerine trinitrate
ICD	International Classification of Diseases
IDDM	insulin-dependent diabetes
IHD	ischaemic heart disease
LBBB	left bundle branch block
MET	metabolic equivalent
MPS	myocardial perfusion scan
NHMRC	National Health and Medical Research Council
NIDDM	non-insulin-dependent diabetes
NSTEMI	non-ST segment elevation myocardial infarct
NSTSEACS	non-ST segment elevation acute coronary syndrome
PCI	percutaneous coronary intervention

PURSUIT	Receptor Suppression using Integrillin
QAS	Queensland Ambulance Service
RBBB	right bundle branch block
SD	standard deviation
ST	ST segment on the electrocardiograph
STEMI	ST segment elevation myocardial infarct
SVT	supra-ventricular tachycardia
TIMI	Thrombolysis in Myocardial Infarction
TNI	troponin

Chapter 1
LITERATURE REVIEW

1.1 Introduction

Chest pain and ischaemic heart disease (IHD) are common presentations to Emergency Departments worldwide. Chest pain has a large differential diagnosis – from serious (myocardial infarct, pulmonary embolism, aortic dissection, etc.) to minor illness (gastric reflux disease), with the challenge of these presentations being to identify the cause of the chest pain concerned. It is often difficult to distinguish between those patients in whom ischaemia is the likely cause, and who require admittance and further examination, and those in whom the pain is unlikely to be caused by ischaemia.

Approximately 25% of presentations fall into the first category (likely due to ischaemia, based on Electrocardiogram and clinical criteria). Of the presentations, 50% fall in a category in which ischaemia is unlikely to be the cause, leaving about 25% of the patients for whom the cause of pain is uncertain (Schaer [1]). If the last category is admitted and investigated, the chance of missing a deadly ischaemic event would be small, though the cost of admittance and medical examination would be very high.

This study examines the outcomes of a group of low-risk patients with uncertain diagnosis, who were seen at a rural health facility. A stress ECG was performed on the patients within 24 hours of the onset of pain, with those with negative tests subsequently being discharged.

1.2 Chest pain: The extent of the problem

In EDs, patients presenting with chest pain form a major portion of the workload.

United States

In the United States, more than 6 million patients with chest pain (cardiac or

non-cardiac type) are admitted to hospitals at a cost of $8 billion annually (Eslick [2]; Cannon [3]). In total, 1.68 million of the patients had acute coronary syndrome (ACS), of which one-quarter presented with acute myocardial infarction (AMI), with ECG ST segment changes and three-quarters (±1.3 million) with unstable angina / non-ST segment changes (Eslick [2]; Cannon [3]).

Australia

> In Australia, according to the Australian Institute of Health and Welfare, 1 446 023 patients were admitted to hospital with IHD from 1998 to 2007 (International Classification of Diseases [ICD] I20–I25: 945 101 men, 500 922 women) (Cardiovascular disease [4]).

Cardiovascular disease in Australia: a snapshot, 2004–2005, published by the Australian Bureau of Statistics, states that,

> *despite steady improvement over the last three decades, cardiovascular disease remains one of the biggest causes of death in Australia and continues to generate a considerable burden on the population in terms of illness and disability... Cardiovascular disease is the most expensive health condition, costing 11%, or 5.4 billion Australian dollars, of the total allocated health system expenditure in 2000–01.* (Cardiovascular disease [4])

In Australia, in 2007, IHD ICD 20 to ICD 25 was the leading underlying cause of death in the case of 22 729 (16%) registered deaths. IHD had been the primary cause of mortality for the previous 10 years, although deaths due to the disease had been declining (from 28 299 in 1998 to 22 729 in 2007), (Causes of death [5]).

South Africa

As this dissertation is for a South African university, the literature review includes statistics from South Africa. Also, similarly to Australia, South Africa has a rural population that is often some distance from tertiary medical care, which makes the management of IHD more difficult.

According to Commerford et al. [6],

> *[r]eliable statistics on health, life-expectancy and disease incidence in Africa are not readily available. The WHO 2007 report ranks the quality of cause-of-death information for most of Africa as low or non-existent. In this regard, Africa does not compare well to the rest of the world, and for much of Africa there is no information. The poor quality of the available information renders definitive comment and prediction problematic*.

In *Heart disease in South Africa* Steyn et al. state that no data exist on the number of heart attacks or strokes that occur in South Africa, though, between 1997 and 2004, 195 people died per day in the country due to some form of cardiovascular disease (CVD). During the years specified, on average 33 people died of myocardial infarctions and approximately 60 of cerebrovascular incidents per day. For every female myocardial death, there were two male myocardial deaths (Steyn [7]; Bradshaw [8]).

In South Africa, deaths before the age of 65 have a significant impact on economic activity. More than 50% of deaths resulting from chronic (including heart) disease were found to occur before the age of 65 years (Steyn [7]; Bradshaw [9]; Pestana [10]).

In the working age group (34–66 years) CVD disease deaths are expected to increase by 41% between 2000 and 2030, resulting in widespread economic impact (Steyn [7]; Leeder [11]).

In South Africa, the highest mortality rates due to CVD are found among those of Indian descent, followed by coloured, white and black people, with the last-mentioned having the lowest rates. Although the mortality rates from CVD for the white and black communities are similar, the specific CVDs differ. For white people, the disease tends to be myocardial infarction and for black people, the disease tends to consist of cerebrovascular incidents, cardiomyopathies and hypertension (Steyn [7]; Norman [12]).

IHD has been in decline in the western/developed world, as the Australian Bureau of Statistics showed in its *Causes of death* [5]. In the United States, from 1994 to 2004 mortality rates due to CVD (ICD-10 I00–I99) declined 24.7%, whereas during the same ten-year period, the number of actual CVD deaths declined by only 8% (Rosamond [13]).

From the above, it is clear that IHD is still a major health problem. Not only does it cause widespread morbidity and mortality, but it also has significant economic implications both for health budgets and for the economy in general. It is also clear that EDs (including rural and remote departments), being the main points of entry for people with chest pain, will, in the foreseeable future, need to cope with ever-growing numbers of patients presenting with chest pain. It is expected that the departments concerned will make accurate diagnoses without unnecessary delays and in the most cost-effective way possible.

1.3 Risk scores and guidelines for diagnosis

As mentioned below, in "Relevance and limitations of the stress ECG (1.6)", approximately 25% of patients with chest pain tend to fall in a grey area, and require more detailed examination to exclude the possibility of coronary artery disease (Schaer [1]).

Boufous et al. state that two-thirds of patients presenting with chest pain are admitted to hospital, only 15% of whom have confirmed AMI [Boufous [14]; Lee [15]). Of the patients discharged from the EDs, an estimated 5% might have a missed AMI, with an associated four times greater mortality (Herren [16]).

Ramsay et al. [17], in their paper comparing risk scores, ask whether clinical features are sufficient for risk stratification. He states that (in relation to ACSs) the following holds:

- Low diagnostic accuracy is achieved when diagnosis is based on ECG and clinical symptoms alone (Goodacre [18]; Bertrand

[19]).

- Chest pain of atypical distribution may indicate a myocardial infarction (Goodacre [20]).Up to a third of patients who develop myocardial infarct do not suffer from typical chest pain.
- Less than half of those admitted with chest pain have ACSs confirmed at discharge (Blatchford [21]), and up to 6% of those discharged from hospital have a missed myocardial infarction (Collinson [22]; which is 1% more than Boufous et al. found, as stated above).

Risk stratification can be employed to improve diagnostic accuracy and to reduce the number of hospital admissions and attendant costs. There are many risk scores, such as GRACE (Global Registry of Acute Coronary Events), TIMI (Thrombolysis in Myocardial Infarction), and PURSUIT (Receptor Suppression using Integrillin). According to De Araujo, GRACE is better at accurate prediction in an ACS population than is either TIMI or PURSUIT (De Araujo Goncalves [23]). Ramsay et al. [17] found that, in patients with suspected cardiac pain in an unselected population, the GRACE risk score is superior to the TIMI risk score and the use of either is better than using ECG and troponin (TNI) testing at presentation. It is clear from the above that some form of risk stratification is needed when evaluating a chest pain patient in an ED.

In Australia, the National Health and Medical Research Council (NHMRC), with the aim of reducing the risk of missing AMIs and of decreasing the number of unnecessary hospital admissions, recommends the use of guidelines, including risk stratification algorithms based on risk scores (Diagnosis and management [24]). The combined application of management strategy and risk stratification is emerging as a new approach to patients with chest pain, rather than merely as a form of establishing a diagnosis (Nichol [25]; Lee [26]).

Although the effectiveness of clinical guidelines is under debate (Thompson

[27]), Boufous et al.[14], in *Impact of a chest pain guideline on decision making*, concluded that following guidelines resulted both in a significant improvement of clinical decision-making in EDs and in reduced repeat presentation with real or potential cardiac chest pain.

The Queensland Health Guidelines, as taken from the *Guidelines for the management of acute coronary syndromes 2006* by the National Heart Foundation of Australia and the Cardiac Society of Australia and New Zealand (Constantine [28]); (cf. section 2.6 below), are used in the current chart audit. The Guidelines seem at least partially, for the intermediate-risk group, to be based on the TIMI risk score.

1.4 Stress-testing modalities

Stress-testing modalities are included in the recommendations of the American College of Cardiology and of the American Heart Association for the diagnosis and risk stratification of patients with known or suspected IHD.

The following modalities are described in "Advantages and limitations of different stress-testing modalities" by D.A. Weiner et al. [29] in *Up to date*:

- treadmill exercise electrocardiography (which is discussed in more detail below)
- exercise radionuclide myocardial perfusion imaging
- exercise radionuclide angiography
- exercise echocardiography

Pharmacologic stress

Pharmacologic stress testing is performed either with dipyridamole or adenosine, or by means of dobutamine echocardiography.

The advantages of treadmill electrocardiography are as follows:

- The equipment is widely available and the cost is low.
- The accuracy has been proven with different populations (132 studies / 24 000 patients), (Gianrossi [30]).
- It is the standard for the assessment of cardiac ischaemia,

functional capacity and prognosis (Garber [31], Gibbons [32], Gibbons [33]).

- The equipment is widely available.
- The accuracy of the test has been tested in different populations.

The disadvantages of treadmill electrocardiography are as follows:

- The sensitivity is lower than with the stress imaging test (Garber [31]).
- A resting ECG with marked ST-T abnormalities will have poor specificity on stress ECG, for example with:
  - the use of digoxin (Gibbons [32]);
  - the left bundle branch block (LBBB), (Gibbons [32]);
  - pacemakers (Gibbons [32]); or
  - patients of the female gender (Morise [34], Melin [35]).

    There is also an inability to localise the extent of the myocardial ischaemia, if performed post-revascularisation (Kafka [36]).

According to San Roman et al., myocardial imaging with Sestamibi was found to have the greatest sensitivity, while echocardiography was found to have the greatest specificity. However, all four stress modalities were found to have similar accuracies and both positive and negative predicative values (San Roman [37]).

Table 1.1: Predicative values of stress modalities

	Exercise ECG	Dipyridamole echocardiogram	Dobutamine echocardiogram	Myocardial perfusion imaging with dobutamine
Sensitivity %				
Overall	66	81	78	87

Specificity %				
Accuracy	70	86	82	81
Predictive value				
Positive	91	96	92	85
Negative	49	73	69	72

For the sake of completeness, the other modalities mentioned are briefly discussed below.

Exercise radionuclide myocardial perfusion imaging

Exercise radionuclide myocardial perfusion imaging uses a radioactive drug to evaluate the coronary blood flow. This drug is spread throughout the heart muscle, proportional to the coronary artery blood flow.

Exercise radionuclide myocardial perfusion imaging has the following advantages:

- the ability to detect CAD and to assess prognosis once confirmed;
- reproducible results;
- the qualitative assessment of left ventricular function (DePuey [38]);
- improved sensitivity and specificity;
- improved determination of the extent of coronary disease and the prognosis thereof; and
- the ability to assess myocardial function.

The exercise radionuclide stress test presents the following problems:

- It is expensive.
- It takes longer, and allows for the risk of exposure to radiation, although in small amounts.
- Purposely trained readers and good quality control of the laboratory are needed to ensure high specificity.

- Artefacts may be due to soft tissues, such as that of the breast, or signal attenuation, caused by the use of a diaphragm.
- LBBB leads to false positive results and low specificity (Tawarahara [39]).

Isotopes used with the radionuclide stress imaging

The following isotopes are used with the radionuclide stress imaging:

- The properties and actions of thallium are as follows:
  - Thallium-201 is a radioactive atom.
  - Thallium myocardial uptake is proportional to flow (Strauss [40]), Nielsen [41]).
  - One injection of thallium-201 can be used both for stress and for resting images, due to its redistribution characteristics (Pohost [42]).
  - Thallium has been validated more extensively for finding viable myocardial muscle (Steien [43]).

- The properties and actions of sestamibi (with Tc 99m sestamibi falls into the isocyanide [isonitriles] class of compounds) are as follows:
  - It has the potential of measuring the resting left ventricular ejection fraction (DePuey [38]).
  - Myocardial uptake is proportional to flow (Glover [44]).
  - There is minimal redistribution over time, giving greater flexibility in planning, because imaging is not necessary immediately after injection. It also fits the long acquisition time necessitated by tomographic imaging well (Glover [44], Okada [45]).

Exercise echocardiography

Exercise echocardiography has the following advantages (Gibbons [33], Fleisher [46], Kafka [36]):

- Sensitivity and specificity are as good as with exercise nuclear

imaging.

- It provides details of the presence and extent of myocardial ischaemia.
- The results are immediately available.
- The ultrasound machine and treadmill are portable.
- It takes less time, and is not as expensive as, exercise nuclear imaging.
- It allows for ventricular function, chamber size, wall thickness and valvular function to be evaluated.
- It can be used to diagnose ischaemia in cases of baseline ECG abnormalities.

The disadvantages of echocardiography include the following (Gibbons [33], Fleisher [46], Kafka [36]):

- Because it is operator-dependent, the interpretation is subjective and not standardised.
- Resting wall motion abnormalities make interpretation problematic.
- Often poor image quality leads to non-diagnostic stress testing.
- Because the echocardiographic stress test is relatively new, it is uncertain whether it can be used for prognosis.
- Current guidelines do not recommend the use of exercise echocardiography with patients with LBBB or paced ventricular rhythm, due to the limited number of studies that have been undertaken so far in this regard.

When a patient cannot exercise, pharmacologic stress testing is possible. Dipyridamole or adenosine is used in radionuclide myocardial perfusion imaging, and dobutamine in echocardiography.

The properties and actions of the drugs are as follows.

- The properties and actions of ***adenosine*** are as follows:
  - It is a naturally occurring substance present throughout the body, with the function of regulating the blood flow in various vascular beds (Akinpelu [47]).
  - Adenosine activates the A1 and A2 receptors (primarily the latter) on the cell surface, which leads to an increase in the cyclic adenosine monophosphate (cAMP), with such an increase leading to an inhibition of calcium uptake by the sarcolemma in the smooth muscle resulting in relaxation and vasodilatation. The relaxation and vasodilatation is attenuated in diseased coronary vessels. Due to such vessels having a reduced coronary flow reserve, they cannot dilate further in response to adenosine. The result is heterogeneity in the blood flow, with healthy and less diseased vessels receiving more coronary blood flow than do their diseased counterparts (Akinpelu [47]).
  - Usually, coronary blood flow does not decrease in the diseased vessels, though, in cases of severe stenosis or total occlusions with compensatory collateral flow, a decrease in blood flow may occur with adenosine, thus resulting in the coronary steal syndrome (Akinpelu [47]).

- ***Dipyridamole*** works by increasing intravascular adenosine levels. It does this by stopping the reuptake and deamination of adenosine. In both cases, a radiopharmaceutical is then injected to visualise the heterogeneity in the coronary blood flow (Akinpelu [47]).

- ***Dobutamine*** is a synthetic catecholamine that stimulates β1 and β2 receptors, leading to an increase in heart rate, blood pressure, and myocardial contractility, thus increasing the regional myocardial blood flow, based on physiological principles of coronary blood flow reserve (Akinpelu [47]).

Dipyridamole and ***adenosine*** have the following advantages:

- They enable those patients who are unable to exercise to be assessed accurately for ischaemia, with preoperative risk assessment in patients with claudication or musculoskeletal problems being examples of such assessment (Akinpelu [47]).
- They are safe for use with selected patients and, if side-effects occur, they can be reversed by stopping the administration of the dipyridamole or adenosine, or by administering aminophylline (Akinpelu [47]).
- They are more specific than is exercise perfusion imaging in patients with coronary disease and LBBB (Akinpelu [47]).

The following problems are present with the use of ***dipyridamole***:

- Functional capacity cannot be evaluated.
- Exercise testing has a greater chance of detecting ECG abnormalities (Akinpelu [47]).
- It cannot be used in the case of any of the following: hypotension, sick sinus syndrome, high-grade heart block (in the absence if pacemakers), or asthma. Patients on oral dipyridamole cannot be tested, and theophylline and caffeine intake must be stopped before testing (Akinpelu [47]).
- Efficacy of medical treatment cannot be assessed by means of repeated pharmacologic stress testing (Akinpelu [47]).
- The coronary steal phenomenon may be caused by the use of dipyridamole (in about 45% of patients) with severe coronary heart disease (Akinboboye [48]).The steal phenomenon can cause subendocardial ischaemia, according to Dahlberg and Leppo:

  > *Overall, these studies of regional coronary flow suggest that several physiologic mechanisms for ischemia with vasodilators are possible. One important implication is that myocardial segments (especially in the subendocardium) may experience an absolute decrease in blood flow that results in ischemic dysfunction that is not detected by imaging of*

regional transmural blood flow. It is also evident that an ischemic ECG response during vasodilator stress is often associated with multivessel coronary disease that has led to collateral development (Dahlberg [49]).

- The specificity is lower in the presence of a right ventricular pacemaker (Skalidis [50]).

Dobutamine echocardiography

Dobutamine echocardiography has the following advantages (Marcovitz [51], Salustri [52], Gibbons [53]):

- Patients unable to exercise can be accurately assessed for ischaemia.
- It accurately identifies the threshold of myocardial ischaemia and the myocardial viability concerned.
- Similarly to exercise stress echocardiography, it measures several parameters, such as total and regional ventricular function, chamber size, wall thickness and valvular function.
- In patients with LBBB, the specificity is higher in regards to finding coronary disease than it is in exercise perfusion imaging (Cortigiani [54]).

The following problems exist with dobutamine echocardiography (Marcovitz [51], Salustri [52], Gibbons [53]):

- It cannot measure functional capacity.
- ECG abnormalities are more likely to occur in exercise testing.
- In obese patients and those with chronic obstructive pulmonary disease, it may be difficult to obtain a good echocardiographic window.
- A highly skilled and experienced operator is needed for the application.
- It is time-consuming.
- In patients with poor left ventricular function and severe CAD, dangerous ventricular arrhythmias may develop.

- In the case of symptomatic aortic aneurism, it is contraindicated.

In a meta-analysis comparing the different chemical stressors (adenosine, dobutamine and dipyridamole), Kim et al. [55] found that adenosine (89%) and dipyridamole (90%) perfusion imaging had the highest sensitivity, dipyridamole echocardiography had the highest specificity (93%), and dobutamine echocardiography had the best combination of sensitivity (80%) and specificity (84%).

1.5 Description and purpose of the stress ECG exercise tolerance test (ETT)

In 1928, Feil and Seigel [56] first reported ST and T changes following exercise in three patients with chronic stable angina. In 1929, Master and Oppenheimer [57] introduced a standardised exercise protocol to access functional capacity and haemodynamic response.

Patients with IHD may have a normal ECG at rest. Exercise may induce ischaemia if the presence of CAD limits flow such that it is insufficient to meet myocardial oxygen demand. This may result in ECG changes, which most commonly take the form of ST segment depression. The modern stress ECG consists of graded treadmill exercise, entailing constant monitoring of the 12-lead ECG. It is used both for diagnosis and prognosis.

According to Hill and Timmis, [58] the ETT can be used in the following instances:

- For the following ***diagnostic indications***:
  - assessment of chest pain in patients with intermediate probability of CAD;
  - arrhythmia provocation; and
  - assessment of symptoms (e.g. pre-syncope) occurring during or after exercise (Hill [58]).

- For the following ***prognostic indications***:
  - risk stratification after myocardial infarction;
  - risk stratification in patients with hypertrophic

cardiomyopathy;

- evaluation of revascularisation or drug treatment;
- evaluation of exercise tolerance and cardiac function;
- assessment of cardiopulmonary function in patients with dilated cardiomyopathy or heart failure; and
- assessment of treatment for arrhythmia.

The Bruce Protocol for ETT is the most widely used, and has been extensively validated. It has seven stages of three minutes each (amounting to a total of 21 minutes), (Bruce [59]). The patient starts at 2.7 km, with 10% incline, and the speed and incline is increased with each stage.

A modified Bruce Protocol may be used in patients after the myocardial infarction. For diagnostic testing, patients are requested to stop taking medications, such as beta-blockers (β-blockers) and digoxin, which might influence the ETT.

ECGs conducted while sitting, standing and hyperventilating are done to rule out possible artefacts due to change(s) in position (such as varying sitting with standing), motion and pH changes (such as with hyperventilation).

The ETT machine monitors the heart rate continuously and a 12-lead ECG is recorded intermittently (though sometimes continuously, depending on the equipment used). Blood pressure is also monitored during the test (Hill [58]). The test must be supervised by a clinician who is experienced in resuscitation, who has a full range of resuscitation equipment available.

Workload and maximum heart rate are also measured during an ETT. Workload is measured in metabolic equivalents (METs). The METs, starting at 2.7 km/h with a 10% incline, should be 4.8. Workload is an indication of oxygen consumption, and hence energy use. The formula in this respect is as follows:

$$1 \text{ MET} = 3.5 \text{ ml oxygen per kg/min}$$

(A workload of 5 METs is necessary to sustain the activities of daily living

(Hill [58])).

Conventionally, the maximum predicted heart rate is taken to be 220 in men and 210 in women, minus the age of the patient. Note worthily, Robergs et al. [60] state:

> *This equation is often presented in textbooks without explanation or citation to original research. In addition, the formula and related concepts are included in most certification exams within sports medicine, exercise physiology, and fitness. Despite the acceptance of this formula, research spanning more than two decades reveals the large error inherent in the estimation of HRmax (Sxy = 7–11 b/min). Ironically, inquiry into the history of this formula reveals that it was not developed from original research, but resulted from observation based on data from approximately 11 references consisting of published research or unpublished scientific compilations. Consequently, the formula HRmax = 220 − age has no scientific merit for use in exercise physiology and related fields*.

A satisfactory response is achieved when 85% of the predicted maximum heart rate is achieved. A good prognostic sign is the reaching of maximum heart rate and stage III of the Bruce Protocol.

1.6 Relevance and limitations of the stress ECG

The ETT has a sensitivity of 78% and specificity of 70% for finding IHD in western populations with high prevalence of the disease. This means that it cannot, on its own, be used to rule out the presence of IHD. The chance of having IHD has to be taken into consideration. In low-risk patients, such as in men who are younger than 30 and in women who are younger than 40 (according to Hill and Timmis [58], Fleisher [46], Gibbons [33]), a positive test is likely to be falsely positive, and in high-risk populations, namely those of 50 years and older, with chest pain, its presence cannot be ruled out on a negative test.

The test must be interpreted in the light of the clinical symptoms, age, gender,

and the prevalence of IHD in the population being tested. The likelihood of obtaining a false positive test is the highest in the case of those with the lowest pre-test probability of the disease, namely in women, young people and those in populations with a low prevalence of IHD.

The attainment of a high workload without symptoms and ECG changes makes the presence of significant obstructive coronary disease unlikely. However, the attainment of a high workload in the case of a high-risk individual does not exclude the development of ACS, as, in such a case, infarction may still result from the rupture of a previously non-occlusive unstable plaque. The ETT has its greatest diagnostic use with the middle-risk group of patients.

Depression of the ST segment is often used as the most important indicator of myocardial ischaemia. However, Hill and Timmis [58] remind us that such an indicator is limited in its usefulness. ST depression occurs in up to 20% of normal people with ambulatory ECGs, as many other causes apart from IHD serve to depress the ST segment. Such causes include repolarisation and conduction disorders, such as LBBB, pre-excitation, and the effect of such drugs as digoxin.

Though the above might lead to the conclusion that ETT is limited in its usefulness in ruling IHD in or out, the following factors need to be considered:

> *Patients with acute chest pain represent up to 20% of emergency hospital admissions, with an estimated > 5,7 million visits per year in the United States alone. In approximately 25% of these visits AMI with typical ECG changes and/or cardiac enzymes rise is diagnosed. In 50% of these visits CAD can be ruled out based on history, clinical examination, ECG findings and serial cardiac markers* (Schaer [1].)

This leaves approximately 25% of patients in a grey area, requiring further examination either to exclude, or to prove, the presence of IHD (Schaer [1]).

The determination of the disposition of patients with chest pain with normal ECGs or no ST segment elevation, and with no TNI rise in ED, is difficult, time-consuming and confusing. According to Sanchis et al. [61], "[d]ecision-making and risk stratification for patients with acute chest pain, non-diagnostic electrocardiogram results, and normal troponin levels are challenging."

Sanchis et al. concluded that chest pain patients with normal ECGs, or with no ST segment elevation and no TNI rise, showed a non-negligible rate of events in one year, and derived a risk score for that specific population that allowed for a more accurate stratification than was obtained with use of the TIMI risk score (Sanchis [62]).The risk score included early stress testing.

The European Cardiology Society Task Force recommends performing a stress test before discharging the patient when severe diseases, such as aortic dissection and pulmonary embolism, have been ruled out, and no chest pain symptoms have occurred for a period of six hours (Erhardt [63]). Combined with clinical criteria, stress testing permits acceptable risk stratification (Atman [64], Sanchis [65], Lauer [66]).

deFilippi et al. [67] conclude that in low-risk patients a strategy of using coronary angiography (CA) has the capacity to detect more CAD than ETT, reducing the need for long-term ED and hospitalisation, and yielding improved patient satisfaction and understanding of their condition. However, the problem is that,

> *for low-risk patients, CA may not be practical at many institutions, because it is not widely available on an immediate basis for non-emergency use. The invasive nature of this procedure will also limit its acceptance for this indication. Current guidelines recommend symptom-limited ETT during the initial* [chest pain unit] *CPU assessment and the consideration of CA in repeat presenters with previous negative cardiac evaluations and with no identifiable sources of symptoms* (deFilippi [67]).

It must also be remembered that CAD, as detected by CA, differs from

myocardial ischaemia detected by ETT, in the sense that CA identifies the presence of anatomical disease in large vessels, whereas ETT examines the *effects* of the anatomical disease. Ischaemia may be present in the absence of anatomical large vessel disease, as in the case of 'Syndrome X'.

1.7 Conclusion

The literature shows that IHD and chest pain are common problems presenting to EDs. Although there is a decline in the numbers of patients presenting with the disease, it is still a significant and costly problem in the western world and is on the rise in the developing world.

With one category of patients it is difficult either to confirm or to refute the presence of IHD without the use of costly invasive measures. Together with risk stratification, ETT can be used to differentiate between those patients who warrant further investigation and those who can safely be discharged.

1.8 Purpose of the study

The challenge of ruling out IHD becomes ever more difficult the further that one is from large metropolitan cities and tertiary medical centres. Rural doctors and emergency physicians working in remote EDs have to send their potential IHD patients to bigger centres for the ruling in or out of disease, which is a time-consuming and costly practice, and which might even lead to a delay in diagnosis and treatment.

Therefore the purpose of the current study is to answer the question whether it is possible for the rural EDs to rule out IHD with a relative degree of certainty and safety in patients, employing the patients' history, a clinical examination, serial TNIs and ECGs, and a stress ECG conducted in the ED.

Chapter 2

STUDY DESIGN & METHODS

2.1 Description of Rockhampton Base Hospital

Rockhampton Base Hospital is a public hospital serving a community of approximately 120 000 people in central Queensland, Australia. It has general physician cover and a coronary care unit (CCU), but, until three months ago, had no cardiology cover. The CM unit of the hospital conducts stress ECGs for the hospital patients, as well as for patients referred by the local general practitioners. Due to the large demand for stress ECGs, the CM unit has difficulty in coping with the workload, with it taking from six months to a year for an outpatient (referred by a general practitioner) to have his/her stress ECG performed.

The hospital has no intervention suite for angiography or PCI. All patients requiring such examination are, therefore, sent to Brisbane (the capital of the state of Queensland, 650 km from Rockhampton) for further diagnosis and treatment. An MPS is available at Rockhampton's private hospital.

Rockhampton's ED annually sees about 40 000 (39 599 from 01-06-07 to 31-05-08) patients, of which 1 599 presented with chest pain or ACS, with 611 being admitted (EDIS [68]), (ICD codes I20.0–I25.9 and R07.1–R07.4).

The ED follows the guidelines laid down by Queensland Health (the state's health department).

2.2 Study design

Between 27-04-06 and 23-04-08, the Rockhampton ED conducted stress ECGs for 331 patients with low-risk features, as per the Queensland Health Protocol (see below). The retrospective study took the form of an audit of the charts of the patients concerned (who formed a convenient sample), with the relevant data being collected to determine whether ED stress testing is a safe

and relatively reliable strategy for use with such patients.

2.3 Subject selection

The Clinical Measurements Department keeps records of all the ETTs conducted by the Rockhampton ED. A list of names of patients who had ETTs done by the ED between the specified dates was obtained.

The following 34 patients, whose names appeared on the list, were excluded from the study:

- those patients not primarily seen by the ED;
- those patients who were referred for ETT to the clinical measurement (CM) unit by the wards of Rockhampton Hospital, or by other hospitals, with the ETT being conducted by one of the emergency physicians; and
- those patients with charts on which the necessary data were inadequately completed or missing.

2.4 Retrospective data

Since the chart audit was conducted retrospectively, the data were only as good as the notes of the attending physician and the quality if the ECG.

2.5 Data collection

A form was developed for the auditing of the charts. The current researcher, together with fellow ED doctors, reviewed the data on the charts, which were obtained from the Medical Records Department of Rockhampton Hospital. Approximately five doctors from other departments in the hospital, or from the ED itself, helped with the data collection. Some of the doctors may have been the treating doctors for the patients being evaluated, but, because of the high staff turnover, it is not possible to say whether any bias might have been present in the collection of the data. The audit was conducted in the computer room of the ED and in the medical library, so that the charts never left the hospital grounds.

The TNI and Emergency Department Information System (EDIS) results

were obtained from the Auslab computer database of the Queensland Health Pathology Service by the current researcher, and from the EDIS computer database / management system program of the ED by those doctors working in the emergency unit who had password access to the systems involved. The data collected on the audit form were filed numerically and then entered onto the Excel© computer database.

2.6 Guidelines

The guidelines used were those of the 'Queensland Health Protocol for Risk Determination of Acute Coronary Syndrome'. The Protocol was taken from the *Guidelines for management of acute coronary syndromes 2006* by the National Heart Foundation of Australia and the Cardiac Society of Australia and New Zealand (Constantine [28]).

The above-mentioned guidelines state that the two objectives in risk stratification are the following:

- to define the likelihood of ACS as the reason for the patient's chest pain; and
- to determine the risk of short-term adverse outcomes, so that a management plan can be developed for the patient concerned.

According to the specified guidelines, patients with ACS are likely to present with the classical picture being prolonged or recurrent central chest pain/ discomfort, although others, especially the elderly, diabetics and women, might present with atypical features. Atypical features are discomfort or pain in the neck, jaw, back or stomach, dyspnoea, diaphoresis, nausea and vomiting.

Age is an important risk factor. In younger patients, the presence or absence of coronary risk factors is considered in full when making a diagnosis, but in the middle-aged and elderly such factors are of less use in diagnosis.

A history of physical or emotional stress increases the likelihood of ACS (Constantine [28], Shah [69]).

The physical examination of patients with NSTEACS is usually normal, with the ECG indicating normal or minor changes in 50% of the cases.

According to the guidelines, diabetes is an independent risk factor for adverse cardiac events. If patients have typical symptoms, diabetes should be regarded as a high-risk feature, with the risk being similar to that of an elevated TNI or ST segment deviation (Roffi [70], Cannon [71]). The guidelines state that the chance of undiagnosed diabetes presenting itself as ACS is quite high (Conaway [72]).

In chronic kidney disease, an increased risk of mortality, recurrent cardiac incidents and bleeding events in patients with a reduced renal function and ACS has been extensively documented (Gupta [73]). From the evidence, a glomerular filtration rate (GFR) of less than 60 ml/min has been found to have a significant negative prognostic impact (K/DOQI clinical practice [74]).

High-risk features

High-risk features include presentation with clinical features consistent with ACS and any of the following (Constantine [28]):

- repetitive or prolonged (> 10 min) ongoing chest pain or discomfort;
- elevated levels of at least one cardiac biomarker (e.g. TNI or creatinin kinase MB fraction [CK-MB]);
- persistent or dynamic ECG changes of ST segment depression equal to, or greater than, 0.5 mm, or new t-wave inversion equal to, or greater than, 2 mm;
- transient ST segment elevation (equal to, or greater than, 0.5 mm) in more than two contiguous leads;
- haemodynamic compromise with systolic blood pressure < 90 mmHg, cool peripheries, diaphoresis, *Killip Class > 1, and/or new onset mitral regurgitation;
- sustained ventricular tachycardia;

- syncope;
- left ventricular systolic dysfunction (left ventricular ejection fraction < 40%);
- prior percutaneous coronary intervention (PCI) within six months, or prior coronary artery bypass surgery;
- the presence of known diabetes (with typical symptoms of ACS); and
- chronic kidney disease (estimated GFR < 60 ml/min; with typical symptoms of ACS).

Killip classification (Killip [75]).

From a study undertaken at a university hospital in the United States of America (including 250 patients, from 24 to 94 years old, with a mean of 64 years), the following nomographic classification could be made:

- **Killip class I** includes individuals with no clinical signs of heart failure. In the above-mentioned study, 81 (32% [27%–38%]) of the patients were found to fall in this class, with their mortality rate being found to be 6%.

- **Killip class II** includes individuals with rales or crackles in the lungs, an S3 gallop, and elevated jugular venous pressure. In the above-mentioned study, 96 (38% [32%–44%]) of the patients were found to fall in this class, with their mortality rate being found to be 17%.

- **Killip class III** describes individuals with frank acute pulmonary oedema. In the above-mentioned study, 26 (10% [6.6%–14%] of the patients were found to fall in this class, with their mortality rate being found to be 38%.

- **Killip class IV** describes individuals in cardiogenic shock or with

hypotension (measured as systolic blood pressure lower than 90 mmHg), and with evidence of peripheral vasoconstriction (oliguria, cyanosis or sweating). In the above-mentioned study, 47 (19%[14%–24%]) of the patients were found to fall in this class, with their mortality rate being found to be 81%.

Intermediate-risk features

Intermediate-risk features include presentation with clinical features consistent with ACS and any of the following intermediate risk factors, as well as not meeting the criteria for high-risk ACS: (Constantine [28])

- chest pain or discomfort within the preceding 48 hours that occurred at rest, or which was repetitive or prolonged (but currently resolved);
- age > 65 years;
- known CAD, with prior myocardial infarction, with left ventricular ejection fraction equal or greater than 40%, or known coronary artery lesion greater than 50% stenosed;
- no high-risk changes on the ECG (see above);
- two or more of the following risk factors:
  - known hypertension;
  - family history;
  - active smoking; and/or
  - hyperlipidaemia;
- the presence of known diabetes (with atypical symptoms of ACS);
- chronic kidney disease (estimated GFR < 60 ml/min, with atypical symptoms of ACS); and/or
- prior aspirin use.

Low-risk features

Low-risk features presentation with clinical features consistent with ACS, in the absence of intermediate-risk or high-risk features. Such features include the onset of anginal symptoms within the preceding month, the worsening in the severity or frequency of angina, or the lowering of the anginal threshold

(Constantine [28]).

2.7 Audit form

The audit form, which was developed with the Queensland Health Guidelines (Constantine [28]) in mind, reviewed the following:

- risk, in terms of:
  - gender and/or age;
  - weight (*obesity, if noted by attending physician on the day of the first presentation that incited the ETT*);
  - hypertension and diabetes (*as per medication taken, previous notes / medication chart*);
  - first-degree family history (*ACS in parents and siblings*);
  - previous history of IHD (*as per history noted by attending physician or notes/reports on chart*) in the form of either angina or myocardial infarction;
  - cardiopathology, such as myopathy (*as per history noted by attending physician or notes/reports on chart*);
  - currently smoking, or ex-smoker (*as per history noted by attending physician or in notes/reports on chart*);
  - hyperlipidaemia (*as per history noted by attending physician or in notes/reports on chart, or drug chart*);
  - renal disease (*as per GFR < 60 on Auslab report*); and/or
  - the presence of pain (*as per history noted by attending physician*), in terms of duration, frequency in the preceding 48 hours; or absence of pain on presentation;
- Transportation (*as per notes/drug sheet obtained from the Queensland Ambulance Service [QAS])* by QAS or other,
- with any of the following having been administered by the QAS:
  - morphine;
  - oxygen (O_2);
  - aspirin;
  - glycerine trinitrate (GTN); and/or
  - other;
- medication administered in the ED or already taken by the patient

(*as per drug chart / notes on chart*):

  - oxygen (O2);
  - morphine;
  - GTN;
  - β-blockers;
  - clopidogrel; or
  - other;

- ECG (*physically available on chart*):
  - number of ECGs undergone prior to the administration of the stress ECG;
  - any ST segment changes;
  - narrow QRS complexes;
  - previous ECG on chart, indicating the possibility of IHD; and
  - post-event ECG indication that the patient visited the ED again with a complaint of chest pain;
- chest X-ray (CXR) undertaken (*as noted by the attending physician / reported on the chart*);
- TNI (*as per Auslab record*), considering the number of TNI tests done, at what time, and the value obtained;
- the stress ECG (*as per ETT noted on the chart*), in terms of:
  - the time and date;
  - the workload achieved;
  - the percentage maximum heart rate achieved; and
  - a positive indication, in terms of:
    - myocardial perfusion scan (MPS) (*as per report on chart*);
    - angiography (*as per report/notes on chart*); and
    - medical admit (*as per notes on chart*);
  - a negative indication (*as per report/notes on chart*);
  - an equivocal indication (*as per report/notes on chart*), in terms of:
    - MPS (*as per report/notes on chart*);

        - angiography (*as per report/notes on chart*); and
        - medical admit (*as per notes on chart*); and
    - (Adverse reactions to the ETT would have been noted here in the medical notes)
        - Date of last visit to ED (*as by Auslab/EDIS*)
        - Follow-up (*as per questionnaire / death register*)
            - Date
            - Alive
            - Dead
        - Cause (*if available*) Any signs, symptoms, tests indicating IHD.

2.8 Questionnaire

A questionnaire was developed by the current researcher, with the help of, and review by, Dr Thompson.

The following questions were asked:

- *Have you had any chest pain or heart problems since your last visit to the Emergency Department?*
- *If yes, did you have a heart attack/angiogram/MPS/other?*

From the questions the current researcher hoped to learn whether, if the patient had experienced more chest pain and/or heart problems after the ETT, there was still a recurring/persistent problem.

The questions were asked in closed or forced format (providing a choice of categories), with:

- the answers being quick and easy to fill in;
- the questions minimising discrimination against the illiterate;
- the answers obtained being easy to record in code, thus facilitating quantitative analysis of the results; and
- the results being easy to report (Leung [76]).

A third question was then asked to obtain the patient's perspective on the whole

process of being evaluated for IHD. The question was asked in closed format (in terms of a differential scale) to give the current researcher an idea of how the patients felt about the process. It is understandable that the experience of chest pain can cause patients stress and fear. Consequently, the question was not intended to judge the medical correctness of the treatment, but rather to discover the experience of the patients of the service provided by the ED. (See Appendix 1 for the questionnaire.)

2.9 Ethical considerations

The study, being a chart review, did not require patient consent. The questionnaire had the approval of the Ethics Committee of the University of Cape Town and of the director of the ED at Rockhampton Base Hospital. Patients' charts never left the hospital grounds, and were only reviewed by medical staff employed by the hospital. All the data were kept on a password-protected computer in a locked office.

2.10 Outcomes to be measured

The endpoint of the study for each patient concerned was likely to be one of the following:

- alive and well, with no signs or symptoms of IHD by date of follow-up contact;
- alive, but with IHD that developed post-stress ECG by date of follow-up contact;
- dead from IHD; or
- dead from another cause.

The IHD was likely to have been diagnosed because the stress ECG was positive or equivocal, and had led to an MPS and/or angiography.

Outcome

The outcome of this study is expected to be confirmation that stress ECG is a safe and reliable option in EDs for those patients with risk-stratifying low-risk chest pain.

Chapter 3
RESULTS

3.1 Data capture

The data capture took the following form:

- 331 ETTs were done by the CM unit with the help of ED doctors.
- 297 audit sheets were entered into the audit.
- 34 audit sheets were rejected, due to the following reasons:
  - 15 were not primarily seen by Rockhampton ED, but were referred by draining hospitals.
  - 13 had so much data missing or such incomplete records that entry into the audit was impossible.
  - 6 had no chart available for audit.
- All of the audit sheets were completed for the 297 charts, but many data points were marked as missing data, due to lack of information noted in the files. The extent of the missing data will be reported and discussed below.

3.2 Basic patient demographics

Table 3.1 below shows the basic gender distribution and age demographics of the patients on whom the audit was based.

Table 3.1: Basic gender distribution and age demographics

GENDER			**AGE**		
Total	**Male**	**Female**	**Mean ± STD***	**Median**	**Range**
297	179	118	50.198 ± 13.81	50	20–87

*STD = standard deviation

3.3 Results

Chest pain

Of the patients experiencing chest pain:

- the median duration of pain was 45 minutes (with the SD being ±702.15 min, or 11.7 h).
- The missing data points were 147 (49.49%), relative to the time

when the chest pain started; and

- 158 (53.19%) patients still had pain on arrival, whereas 112 (37.71%) were pain-free, as noted by the nurse in the patient's observation sheet.
- The missing data points were 27 (9.09%).

Age of patients

As Figure 3.1 below shows, of the male patients:

- 15.08% fell in the category 'equal & older than 65 years', and therefore fell in the intermediate-risk group;
- 8.41% fell in the category 'younger than 30 years'; and
- 76.51% fell in the category ' equal & older than 30, but younger than 65, years'.

The category of men 'younger than 30 years' was created because, in this category, false positive ETTs were found to be more prevalent than they were in the other categories.

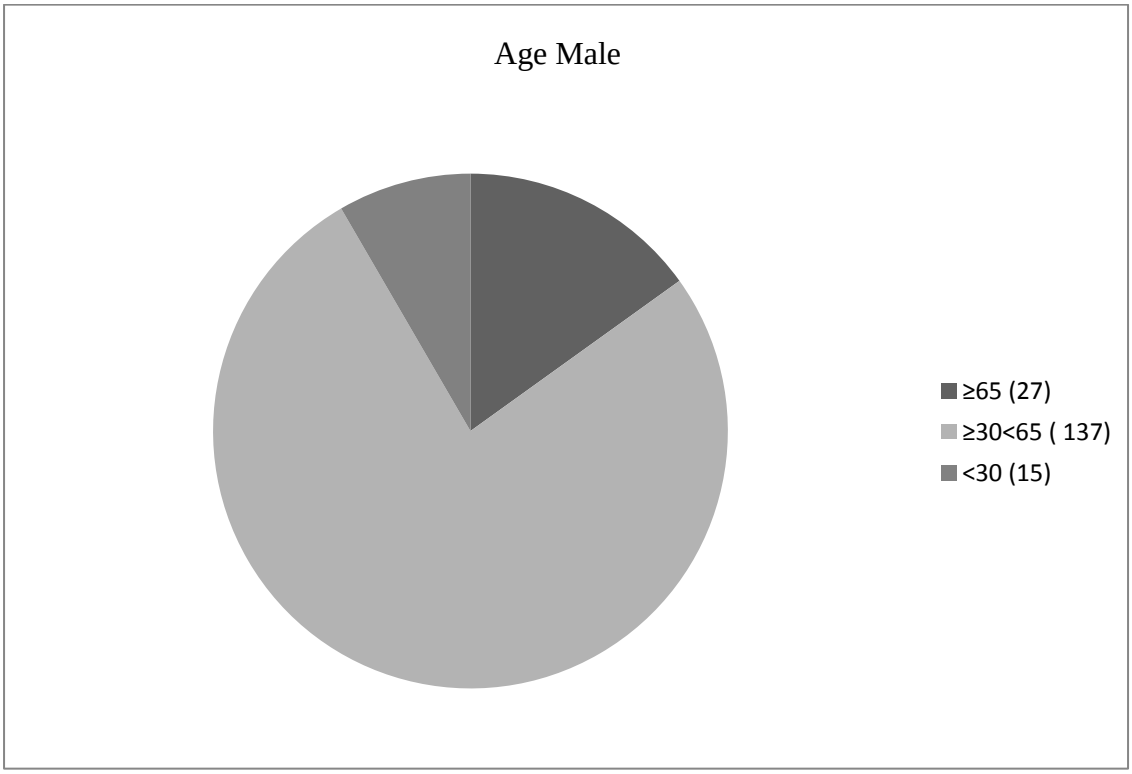

Figure 3.1: Age of male patients

As Figure 3.2 below shows, of the female patients:

- 14.40% fell in the category ‘equal & older than 65 years’, and therefore fell in the intermediate-risk group;
- 15.25% of women fell in the category ‘younger than 40 years’; and
- 70.33% of women fell in the category ‘equal & older than 40, but younger than 65, years’.

The category of women ‘younger than 40 years’ was created, because in this category, false positive ETTs were found to be more prevalent than they were in the other categories.

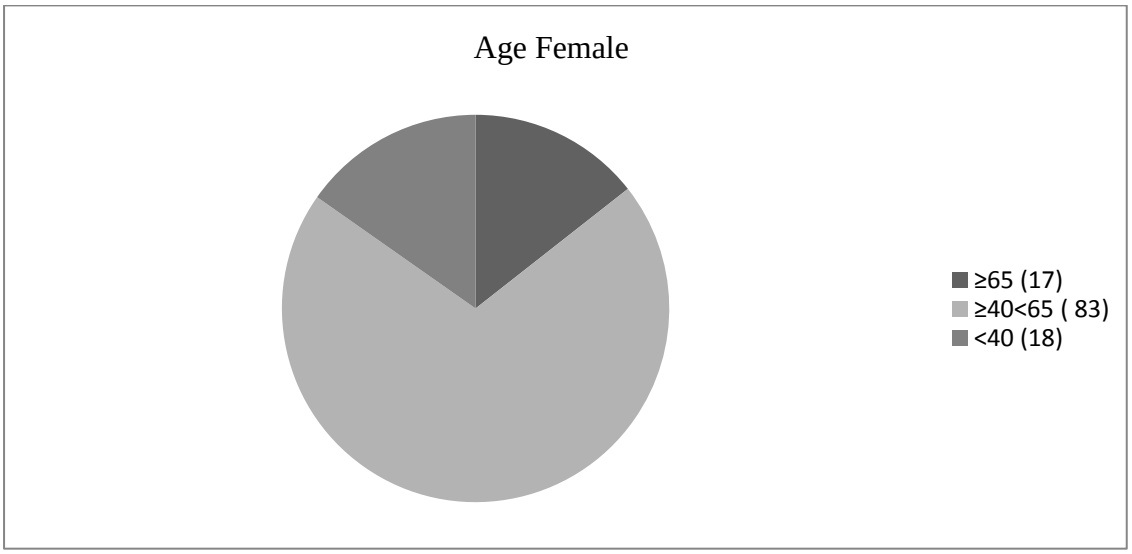

Figure 3.2: Age of female patients

Diabetes status of patients

As Figure 3.3 below shows, of the patients:

- 11.45% had diabetes, and therefore fell in the intermediate-risk group (10.78% non-insulin-dependent diabetes [NIDDM] + 0.67% had insulin-dependent diabetes [IDDM]; (10.78% +0.67%=11.45%)

and

- 72.38% did not have diabetes, and, depending on the other risk factors, might have fallen into the low-risk category.

Of the charts, 16.17% had information missing, so that the diabetes status of the patients concerned was unknown.

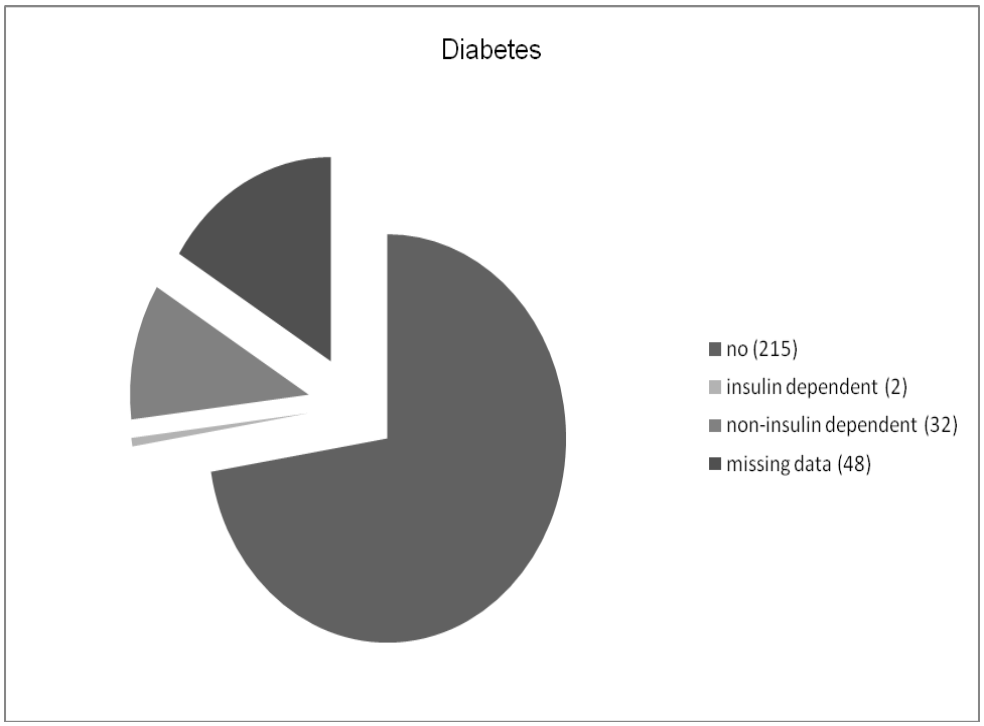

Figure 3.3: Diabetes status of patients

IHD status of patients

As Figure 3.4 below shows, of the patients:

- 13.8% had had previous IHD, and therefore fell in the intermediate-risk category; and
- 64.3% had had no previous IHD.

Information relating to IHD was absent from 21.90% of the charts.

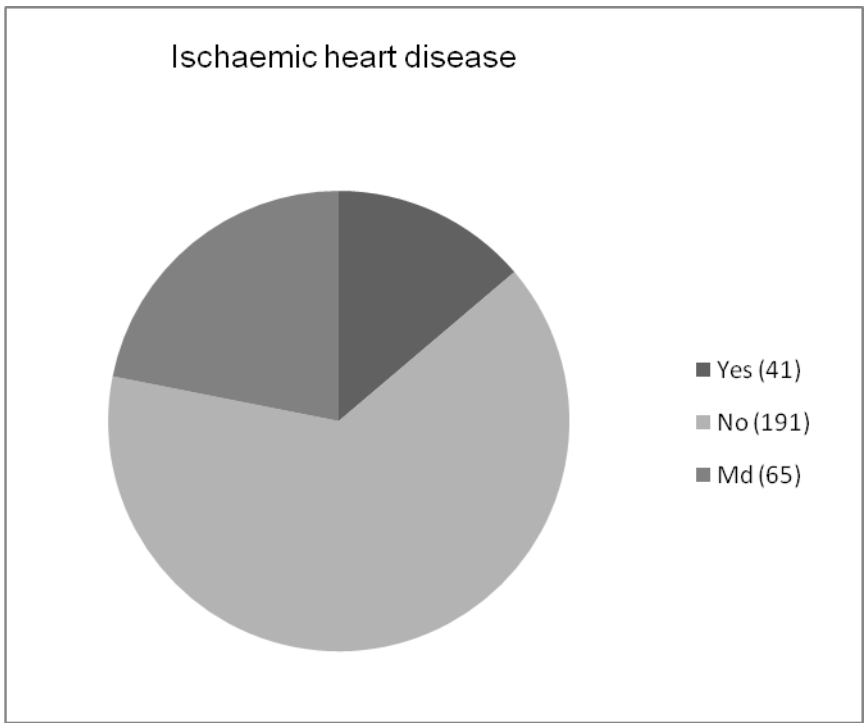

Figure 3.4: IHD status of patients

Individual risk factors of patients

As Figure 3.5 below shows, of the patients:

- 32.32% (96) had hypertension, 53.19% (158) did not, and for 14.47% (43) the relevant data points were incomplete;
- 33.33% (99) had a positive family history for IHD, 39.05% (116) had no positive history of IHD, and for 27.6% (82) the relevant data points were incomplete;
- 34.34% (102) were current smokers, 33.33% (99) did not smoke, 18.85% (56) were ex-smokers, and for 13.46% (40) the relevant data points were incomplete; and
- 29.26% (88) responded positively for dyslipedaemia, 27.94% (83) negatively, and for 42.42% (126) the relevant data points were missing.

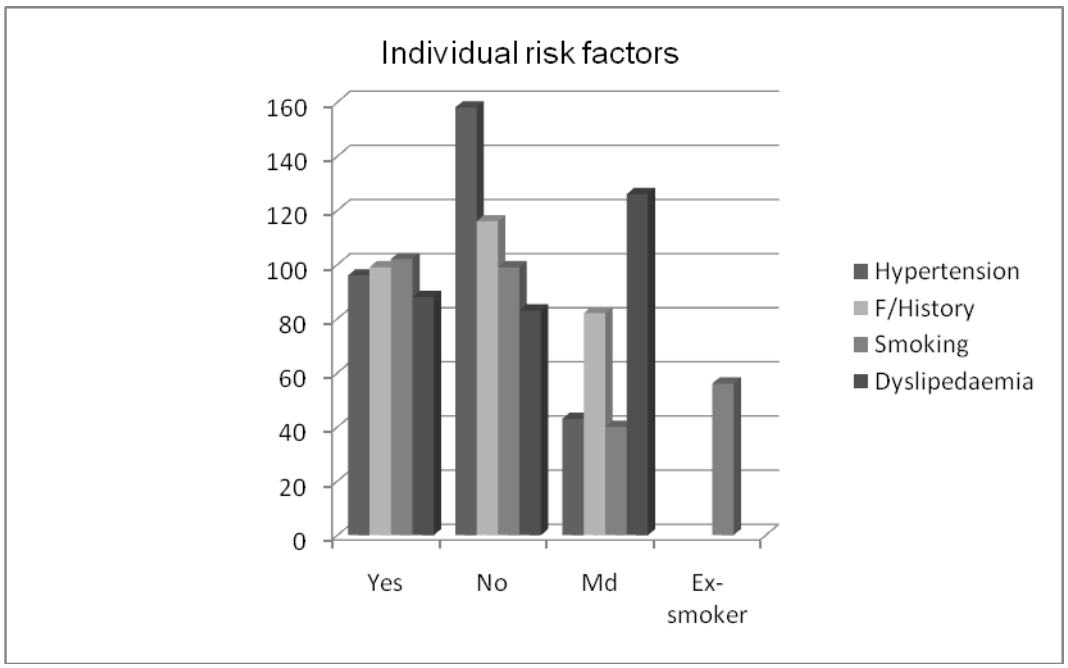

Figure 3.5: Individual risk factors of patients

Patients with one or more risk factors

In order to fall in the intermediate category, two or more risk factors were necessary. Of the patients with one or more risk factors (see Figure 3.6 below):

- 37.71% (112) had *one* risk factor;
- 26.59% (79) had *two* risk factors;
- 11.11% (33) had *three* risk factors;
- 1.34% (4) had *four* risk factors; and
- 23.23% (69) had *no* risk factor.

The missing data points in the audit of risk factors were as follows:

- 34.34% (102) had *one* missing data point
- 15.82% (47) had *two* missing data points;
- 5.7% (11) had *three* missing data points; and
- 37% (120) had *no* missing data point.

Figure 3.6: Patients with one or more risk factors

Changes in ECG while patients in ED

The changes in the ECGs undertaken while the patient was in the ED on the presenting date revealed the following regarding the 297 charts reviewed:

- 290 ECGs were in sinus rhythm, and of the seven other charts:
  - two ECGs had not been performed;
  - four ECGs showed the presence of supraventricular tachycardia (SVT); and
  - one ECG was missing;
- 285 ECGs had no ST segment changes, and of the other 12 charts:
  - two ECGs had not been performed;
  - one ECG was missing; and
  - nine (including 4 SVT ECGs) had ST segment depression;
- 284 ECGs had narrow QRS complexes (<120ms; no inter-ventricular conduction delay, and of the other 13 charts:
  - two ECGs had not been performed;
  - one ECG was missing; and
  - ten ECGs had RBBB (right bundle branch block; with no

ECG having LBBB).

Chronic renal disease

Regarding chronic kidney disease, as estimated by GFR < 60ml/min:

- GFR > 60ml/min = 236 patients (79.46%);
- GFR < 60ml/min = 4 patients (1.34%); and
- missing data = 57 patients (19.19%).

Prior aspirin

Regarding prior use of aspirin:

- 36 (12.12%) patients, all of whom had a history of IHD, were taking aspirin prior to the presenting date;
- 196 (65.99%) patients were not taking aspirin; and
- there were 65 (21.88%) missing data points.

CXR

Regarding the undergoing of CXRs:

- 266 (89.56%) patients had undergone a CXR as part of the medical examination protocol.
- 19 (6.39%) patients had not undergone a CXR; and
- there were 12 (4.04%) with missing data points.

TNI testing

The current protocol at Rockhampton Hospital for TNI and ACS workup requires at least two negative TNI tests: one on arrival and one preferably eight hours after the chest pain episode. This is in accordance with the recommendations of the 2006 *Guidelines for the management of acute coronary syndromes* (Constantine [28]).

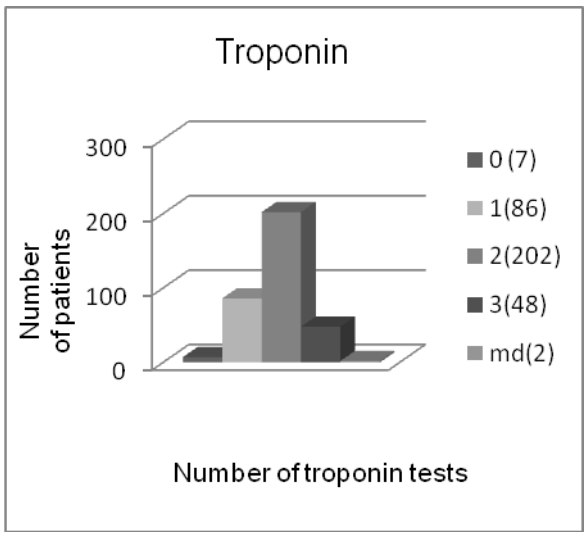

Figure 3.7: Number of TNI tests per patient

As Figure 3.7 above shows, of the patients:

- 2% had undergone *no* TNI blood test;
- 25% had undergone *one* TNI blood test;
- 58.5% had undergone *two* TNI blood tests;
- 14% had undergone *three* TNI blood tests; and
- there were 0.5% with missing data points.

Audit: time of TNI testing

Table 3.2: Time from presenting in the ED to first TNI test (all 288 first TNI)

	h: min: s
Median	00:41:00
Average	1:21:07
SD*	2:32:31
Maximum	19:57:00
Minimum	**-03:18:00

*SD = standard deviation

**Denotes blood taken by nursing staff and sent to the laboratory before the doctor had seen the patient, or time of presentation not corrected on the EDIS computer program by the attending physician.

Table 3.3: Time from presenting in the ED to first TNI test (86 single TNI testing)

	h: min: s
Median	00:47:30
Average	1:26:45
SD	2:44:12
Maximum	18:42:00
Minimum	*-03:18:00

*Denotes blood taken by nursing staff and sent to the laboratory before the doctor had seen the patient, or time of presentation not corrected on the EDIS computer program by the attending physician.

The following findings were made regarding the 86 patients who underwent only a single TNI testing:

- Four TNI tests were conducted eight or more hours after presenting.
- 82 patients underwent only one TNI test before the eight-hour protocol mark. (The timing of the test was in accordance with the time of presentation in the ED. Though it would have been better to use the time that the chest pain started, such information was too poorly noted on the patients' charts to be of any value.)

Table 3.4: Time from presenting in the ED to second TNI test

	h: min: sec
Median	07:33:00
Average	21:03:21
SD	8:47:13
Maximum	8:06:00

In respect of those patients who underwent a second TNI test:

- In total, 202 (58.550%) patients underwent a second TNI test, of which:
  - 48 (23.762%) underwent the second test after eight hours; and
  - 154 (76.237%) underwent the second test prior to the elapse

of the permissible minimum of eight hours.

ETT

Of the 297 charts reviewed:

- 28 ETTs were positive for IHD as follows:
  - There were 14 male and 14 female patients in this category.
  - The median age of the patients was 56.5 years.
- The 28 ETTs were found to be as follows:
  - 12 MPSs, which were normal
  - 2 MPSs, which showed signs of prior IHD;
  - 5 patients, who had been admitted to the medical ward or to a CCU ward
  - 4 CA, which were normal;
  - 3 CA, which were abnormal; and
  - 3 with missing data.
  - Please note that one patient was both admitted and had a CA explaining the 29 tests/admissions for the 28 ETTs done.
- The 75 equivocal ETTs were found to be as follows:
  - There were 47 male and 28 female patients.
  - The median age of the patients was 55 years.
- The 75 ETTs were found to be as follows:
  - 41 MPSs, which were normal;
  - 14 MPSs, which showed signs of prior IHD;
  - 6 patients, who had been admitted to the medical ward or CCU;
  - 1 CA, which was normal;
  - 2 CAs, which were abnormal; and
  - 13 with missing data.
  - Please note that two patients were both admitted and had CAs explaining the 77 tests/admissions for the 75 ETTs done
- In total (all risks):
  - 69 MPSs had been undertaken, of which 53 had presented as normal and 16 had shown signs of IHD (i.e. decreased left ventricular ejection fraction and/or ischaemia);

  - 11 patient had been admitted to the medical ward or CCU; and
  - 10 CAs had been performed, of which 5 had shown abnormalities.

- 193 ETTs were negative:
  - There were 118 male and 75 female patients is this category.
  - The median age of the patients was 48 years.

Low-risk category

- Of the patients who had undergone ETTs, 143 (48.14%) fell into the low-risk category (as per the Queensland Health Guidelines), (Constantine [28]):
  - 13 ETTs were positive for IHD, which were found to be as follows:
    - one MPS, which had shown signs of IHD;
    - two patients, who were admitted to the medical ward or CCU, with one having a myocardial infarct;
    - two CAs, which were normal; and
    - two patients with an MPS booked, but whose results were not on the chart; and
    - one with a missing data point.
- There were 85 male, and 58 female, patients in this category.
- The median age was 44 years.
- The 28 ETTs that were equivocal for IHD were found to be as follows:
  - 18 MPSs, which were normal;
  - three MPSs, which showed signs of prior IHD;
  - one patient admitted to the medical ward or CCU;
  - one CA, which was normal;
  - two MPSs without results indicated on the charts;
  - one patient with a 24-hour Holter monitor, which was normal;

- one patient with a cardiac ultrasound scan; and
- one with a missing data point.

Intermediate-risk category

- Of the patients, 154 (51.85%) who had ETTs fell into the intermediate-risk category, in respect of whom the following pertains:
  - There were 94 male and 60 female patients is this category.
  - The median age of patients was 56 years.
  - Eight ETTs were positive for IHD, which consisted of:
    - two MPSs, which were normal;
    - one MPS, which showed signs of prior IHD;
    - three patients admitted to a medical ward or CCU (with one being admitted in Brisbane);
    - two CAs conducted, of which one was normal and
    - none with missing data points.
  - The median age for the group of patients with negative ETTs for IHD was 66 years. 13 of the group had had more tests done, consisting of:
    - eight MPSs, which were normal;
    - five 24-hour Holter rhythm monitors, of which one showed paroxysmal atrial fibrillation;
    - one patient admitted to a medical ward or CCU;
    - one patient with both a Holter and an MPS.
  - Of the ETTs, 36 were equivocal for IHD, consisting of:
    - 21 normal MPSs;
    - five MPSs, which showed signs of prior IHD;
    - two 24-hour Holter rhythm monitors, which were normal;
    - one patient admitted to a medical ward or CCU;
    - one patient who underwent a cardiac ultrasound;
    - one patient who was reviewed in the medical

outpatients department;

- three patients who underwent more than one test;
- one missing result; and
- one patient with a cardiac ischaemic event after the date of presentation, which was then audited (02-06-08).

Relationship between the time of presenting and the date when the ETT was conducted

The relationship between the time of presenting and the date when the ETT was conducted consisted of the following:

- 88 ETTs were done on the day of presentation to the ED;
- 107 ETTs were done the day following the presentation to the ED;
- 96 ETTs were done later;
- The 88 ETTs done on the same day were carried out between 00:00:00 and 15:30:00, with the median time for the period being 09:32:30 (SD ±03:31:52).
- Three of the patients with missing data points on their charts fell into this category.

Survival after presentation to the ED and the subsequent ETT

In terms of survival after presentation to the ED and the subsequent ETT:

- None of the 297 patients could be found on the Queensland death register for the period 24-04-06 to 30-11-08.
- Of the 297 questionnaires sent out, 116 (39.05%) were submitted on completion, with the 23 returned unanswered to the sender, and the 108 who failed to respond, amounting to 44.10% of the total.
- Of the 116 who responded, 27 (23.27%) reported having experienced a chest pain episode of some sort after the event that had brought them to the ED in the first place. Of the 27 patients with post-event chest pain:
  - one had a myocardial infarct;
  - four had CAs;

  - four had MPSs;
  - two had another ETT; and
  - one had a cardiac ultrasound.
- On auditing the last dates found on Auslab and EDIS, the following was found:
  - 122 patients had dates entered into the systems after the date of the ETT.
  - The median for the period concerned was 213.5 days (with the SD being ±218.46 days).
  - The minimum period after the ETT was one day.
  - The maximum period after the ETT was 814 days.

The following endpoints were measured:

- Alive and well, with no signs or symptoms of IHD by date of follow-up contact, as follows:
  - 297 − (16+5+11+12) = 253(± 16 unknown patients)
    - Total ETT – (Positive PMS + Positive CA + Admitted patients + Chest pain post ETT)

- Alive, but with IHD that developed post-stress ECG by date of follow-up contact, as follows:
  - 27 out of 116 questionnaire replies showed recurring chest pain.
  - 12 out of the 27 had further investigations for ACS.
- Death from IHD, as follows: nil (none for the period 2006-04-24 to 2008-11-30).
- Death from another cause, as follows: nil (none for the period 24-04-06 to 30-11-08).

  No deaths were recorded in the death registry but I have to conceded that there is a possibility that some patient may have died in another State of the Commonwealth of Australia and there for not recorded in the Queensland registry.
- IHD diagnosed, because the stress ECG was positive or equivocal,

and had led to an MPS and/or angiography:

- 28 ETT were positive and 75 equivocal for IHD (total: 103), with:
  - MPS, with 16 positive, and 53 negative, for IHD;
  - CA, with 5 positive, and 5 negative, for IHD;
  - 11 admitted; and
  - 16 unknown.

Chapter 4

DISCUSSION

When a patient presents to the Rockhampton ED complaining of chest pain, it is expected that the patient be treated according to the guidelines of Queensland Health (Constantine [28]). Once it has been decided that the patient has neither an ST segment elevation myocardial infarct (STEMI) nor non-ST segment elevation myocardial infarct (NSTEMI), or any other life-threatening pathology, such as an aorta dissection or a pulmonary embolism, the patient must be risk stratified to enable the doctor concerned to develop the appropriate investigative strategy and treatment options.

In Chapter 1 – Literature Review, the problems with risk stratification was already mentioned. These being:

- Low diagnostic accuracy when diagnosis is based on ECG and clinical symptoms alone.
- Chest pain of atypical distribution may indicate myocardial infarction. Up to a third of myocardial infarction patients may have atypical chest pain.
- Less than half of those admitted with chest pain have ACS confirmed at discharge and up to 6% of those discharged have a missed myocardial infarction
- Risk stratification is employed to improve diagnostic accuracy. There are many scores eg. TIMI, GRACE and PURSUIT, some better than others but all better than using an ECG and troponin at presentation alone.

In Rockhampton ED, the patients classed as low-risk are supposed to be admitted to the ED Observation Unit (EDOU) to await the second TNI test, which should be conducted eight hours after the onset of pain. The patient is admitted to the observation unit so that an evolving myocardial infarction may be identified. Such identification is important, seeing that a study by Millar et al. (Millar [77]) shows that 5% of 4 136 patients were found to have

an evolving myocardial infarct. Intermediate-risk and high-risk patients should not be admitted for ED observation, but should be referred medically for admittance to the medical ward or CCU.

After the second negative TNI test, the patient should undergo an ETT (if physically possible) to conclude the cardiac examination and to identify the IHD. If the ETT is positive or equivocal, the patient must then progress to an MPS or to an angiography.

One of the main findings of the audit is the poor compliance of the ED doctors with the prescribed guidelines on the management of chest pain. The finding will be discussed before assessing the primary objective of the study, namely the safety and efficacy of performing an early ETT on rural populations in the case of low-risk chest pain patients, to enable the selection of those who require admittance and further medical investigations.

Chest pain data, particularly as regards the start and duration of such pain, were poorly documented. The poor documentation compromised both the timing of the TNI tests and the risk stratification.

With regards to risk stratification, patients with the following risk factors fell into the intermediate-risk group and should have been admitted rather than being observed in EDOU and ETT, namely those:

- 65 years & older;
- with diabetes;
- with renal disease;
- and with two or more of the following:
  - hypertension;
  - a family history of IHD;
  - a current habit of smoking; and
  - known dyslipidaemia.

There was also a failure to perform necessary investigations, as can be seen from the following:

- in respect of ECGs, the indefensible failure to record the conducting of any ECG in the case of two patients;
- in respect of CXRs, the indefensible failure to perform a CXR on 19 patients, so as to exclude alternative serious causes of chest pain, such as aortic dissection; and
- in respect of TNI testing, the failure to follow the guidelines as to the time and quantity (two) of the tests required, which might have led to a failure to diagnose myocardial infarctions.

All of the above failures to follow the appropriate guidelines were also compounded by very poor data recording.

A large number of intermediate risk patients underwent EDOU admissions and ETT, which was contrary to the guidelines that recommend formal admittance and workup. The four patients with SVT were also inappropriately investigated and treated.

The problems discussed above may have been due to a range of factors, including: ignorance, insufficient commitment to data collecting, and arrogance.

In an interview, Dr Goodman expressed a belief that the main problem was that doctors do not like using risk stratification tables.

> *We like to use our common sense in these matters – to look at a patient and make a decision – to use our heads over formulas. We have been taught that way. We like to think of medicine as an art rather than a science, and most doctors know what the guidelines are, but we don't take a standardize[d] approach to risk stratification at the bedside. I think it is very much the exception that risk scores are routinely applied. And this is a big part of why the wrong patients are getting referred for catheterization, or in the case of the audit for exercise tolerance testing* (Wrong ACS patients [78]).

The efficacy and safety of the ETT performed in accordance with ED protocol prior to the discharge of a chest pain patient

Efficacy

Of the 28 positive ETTs, 13 fell in the low-risk group, 8 in the intermediate-risk group and 7 in the high risk group. Positive ETT results were followed by more invasive testing, resulting in confirmation of ischaemia in 4 of the patients. The finding of false positive ETTs in the younger patients came as no surprise. However, the finding of a negative ETT in the younger group is useful, in that it makes ischaemia unlikely to have been the cause of the chest pain experienced. Despite this general rule, one patient in the younger group had a myocardial infarct. It is known that a small unstable plaque, which caused no ischaemia during the ETT, can, nevertheless, rupture and result in thrombosis.

Of the 75 equivocal ETTs, 8 resulted in a diagnosis of ischaemia. Though the yield concerned was low, the patients concerned would have otherwise remained undiagnosed. Very importantly, those with a negative ETT were saved the cost, inconvenience and potential danger of more invasive testing. Of the patients with negative ETT, 13 underwent further investigations for reasons that were either unclear or unknown.

Safety

No adverse events were reported as occurring during the ETT, even with those at intermediate risk. No deaths among the study group were recorded in the Queensland death register up to November 2008.

A more detailed discussion of the individual data points and their outcome is presented below.

4.1 Chest pain

The data in terms of chest pain category (consisting of duration, frequency, and pain-free at presentation) were very badly noted on the charts.There is a major discrepancy between the 49.49% missing data points for the *duration*

of pain and the 9.09% missing data points for *pain-free on arrival* at the ED. This is due to the fact that it could be deduced from the nursing observation sheet (on which the first observations are recorded on arrival) whether or not the patient was pain-free. The attending doctors' notes had to be relied on for the duration of chest pain which, as indicated by the almost 50% missing data points, were very poorly recorded on the patients' charts.

4.2 Age

Of the patients, 15% (27) of the men and 14.4% (17) of the women were older than 65 years. Such patients automatically fell into the intermediate-risk category, and should have been admitted to the medical ward, and not to the EDOU.

Of the patients, 8.37% of the men were younger than 30 years old, and 15.25% of the women were younger than 40 years old, so that the ETT was more likely to give false than true positive values (Hill [58]).

If risk profiles of younger patients are strongly suggestive of IHD, it might be better, from the start, to use tests that tend to give fewer false values, such as cardiac ultrasound and/or MPS.

4.3 Diabetes and IHD

Of the patients, 11.45% had diabetes and 13.8% had prior IHD, so that they fell into the intermediate-risk group, members of whom should not have gone to the EDOU, and on to the ETT pathway, but who should rather have been admitted to the medical ward. A concern here is that 16.16% of diabetic patients and 21.89% of IHD patients did not have the appropriate data points evaluated. Of the patients, 4.04% (12) had both diabetes and IHD, so that they should also have been admitted by medical team.

4.4 Hypertension, positive family history of IHD, current smoking habits, and dyslipidaemia.

Patients who had two or more of the following criteria fell in the

intermediate-risk categories: hypertension, a positive family history of IHD, current smoking habits, and dyslipidaemia. The details of such patients were also particularly badly noted on the charts, with the number of missing data points being as follows:

- 14.47% for those patients with hypertension;
- 27.6% for those patients with a positive family history of IHD;
- 13.46% for those patients with a current smoking habit; and
- 42.42% for those with dyslipidaemia.

Of the patients, only 37% (120) had all four data points complete, and had therefore been correctly evaluated respecting the data points.

Nevertheless, of the patients there were 39.05% (116) with two or more of the risk factors, (of which 26.59% [79] had two; 11.11% [33] had three; and 1.34% [4] had 4), all of whom should have been admitted

4.5 ECG

Of concern in this category were two patients who did not have an ECG done for the evaluation of chest pain. It was also noted that four patients with SVTs were sent to the EDOU for observation, serial TNIs, ECGs and ETT, despite the absence of ischaemia. Although IHD can cause arrhythmias and ETT, according to Hill and Timmis (Hill [58]), it can be used as an aid for diagnosing arrhythmias, so that such patients might benefit more from going the medial route, since most SVTs are not caused by IHD. The EDOU serial pathway is mainly for ruling out ACS in patients, rather than for the evaluation of arrhythmias.

4.6 Renal disease, prior aspirin use, and CXR

Four patients, who should have gone on the medical pathway, had GFR < 60 ml/min. All those patients who had previous IHD had prior aspirin use, as was to have been expected. Aspirin usage (75 mg to 100 mg) is recommended in the 2006 guidelines for the management of ACSs (Constantine [28]).

CXRs are done to exclude other possible causes of chest pain. A total of 6.39% (19) patients did not undergo a CXR and 4.04% (12) of the data points were missing. The concern, again, is that other possible causes of chest pain might be overlooked.

4.7 TNI, time and pain

According to the guidelines for the management of ACSs, the TNI level should be checked on arrival. The rationale is that a rise in TNI levels indicates the presence of myocardial necrosis, which is a high-risk feature in NSTSEACS.

TNI is the preferred marker, because about a third of patients with elevated TNI, but with normal creatinin kinase (CK) and CK-MB levels, are likely to develop an adverse outcome. TNI testing should be repeated eight hours or more after the last episode of pain or other symptom of coronary

insufficiency, if the testing is initially negative. The rationale behind the repeat test is that TNI elevation is often delayed by four to six hours; therefore, repeat TNI testing is necessary for identifying patients at high risk who might benefit from aggressive therapy and early invasive strategy (Constantine [28]).

None of the patients had a positive TNI test, which would have placed them in the high-risk category. It is, however, of concern that 2.36% (7) of the patients had no TNI level assessment performed, with 28.96% undergoing only one assessment. The median time for the testing of all first TNI levels was 41 minutes from arrival to result, according to the Auslab pathology computer system. Such a median time may be acceptable if the time it took to assess the patient, to obtain the initial ECG and set of observations, and to obtain the blood sample, as well as to label it and to send it to the laboratory, is taken into account.

However, the SD of 2 hours and 32 minutes means that the blood sample could have been taken well before/after the 41 median minutes after arrival. It has to be noted that some values were negative, indicating that the blood sample was taken before the doctor had seen the patient. The timing of such blood samples has two possible explanations:

- The attending nurse took the blood sample, and recorded the ECG during the initial assessment, before the doctor had seen the patient.
- The attending doctor saw the patient on arrival and did not enter the details of the consult immediately onto the EDIS computer system. When, finally, the doctor did log onto the computer management program, the time of logging in was not corrected to indicate that of the consultation.

From personal observation, it is clear that both the above situations tend to occur. However, it is beyond the scope of the current audit to evaluate the practice and the influence thereof.

It can be argued that one TNI measurement is adequate if the last episode of

pain occurred at least eight hours before the arrival of the patient at the ED, provided that the patient has been pain-free for the intervening period. Of the patients who had only one TNI level tested, four TNI levels were tested eight hours after the patient had first presented to the ED, and 84 were conducted before eight hours had elapsed. The median time for the 'once only' TNIs was a concerning 47 minutes (with the SD being 2 hours and 44 minutes). Clearly, not all of the 84 patients fell into the category described at the outset of the paragraph; therefore, at least some of them were at risk of having an evolving myocardial infarct, which would not have been detected.

Miller et al. [77] alleviate some of the fear of missing an evolving myocardial infarction, saying:

> *...our results show that on the whole emergency physicians are doing a good job in picking up the patients with evolving myocardial infarction* ***before conclusive Troponin*** *tests are in. It was hard to tell from this study which factors are the most important in identifying these patients. It was a combination of findings from the patient's history, clinical examination, and ECG. But what we have shown is that the emergency doctor's* ***best guess*** *is usually right in finding the patients.*

Observing the patient for a period of eight hours prior to the start of the second TNI test after the last episode of chest pain is necessary. In the current study, such a period of observation is extremely problematic to evaluate, due to the bad notation of the time and of the duration and frequency of pain by the attending doctors on the patients' charts.

Of the patients in the current study, 53.19% (158) had pain on arrival.

With 202 second TNI tests being undertaken, 68.10% of the patients underwent a second TNI test, though only 48 (16.16%) of the tests were performed eight hours after the patient first presented to the ED.

The duration of pain had a median length of 45 minutes (with SD of 702.15 min). The guidelines for the management of ACS clearly state that high-risk

features include presentation with clinical features consistent with those of ACS and repetitive or prolonged (> 10 min) ongoing chest pain or discomfort.

The 145 patients who had chest pain (presumed to be ischaemic) for longer than ten minutes fell into the high-risk category and should have been admitted to a CCU, which clearly did not happen. The reason for this might be that the attending doctors could have had different understandings of the clinical features of ACS.

Although the clinical features of ACS are taught in the first years of clinical practice, Lee et al. [79] found that doctors tend to risk stratify incorrectly, tending to underestimate the risk concerned, and, therefore, not sending their patients for PCI. In their study, 35.3% (753) of patients were not referred for catheterisation, though 51.1% (305) of them were found to have had intermediate or high TIMI scores on review of their classification, so that they should have been considered for catheterisation.

4.8 ETT

The EDOU pathway was considered to be suitable for low-risk patients, as defined by the Queensland Health guides, but the current audit discovered that more (namely 155 or 52.18%) intermediate-risk patients were on it than were low-risk patients (comprising 142 or 47.81% of the total). The low-risk category delivers more positive ETTs than does the intermediate-risk category at 9.15% (compared with 5.16% of the intermediate category). The low-risk category also contained one myocardial infarction.

One reason why the low-risk category might have contained more positive ETTs is that the group concerned tended to consist of men below 30 years in age and women below 40 years in age (with the median age being 44 years). As we know from Hill and Timmis (Hill [58]), these age groups have a tendency to indicate false positive tests.

Surprisingly, in the intermediate category a group of 13 patients who had a

negative ETT, were, nevertheless, found to have undergone other cardiac tests. In the group, eight MPSs and five 24-hour Holter monitoring were recorded, with one patient being noted as having undergone both. The cardiac examination for the patients concerned should have ended with the negative ETT. The reason why the doctors continued with the testing in such cases is unknown, though it might have been that the risk stratification was incorrect.

The 88 ETTs that were done on the same day showed that presentations to the ED between 00:00 and 15:00 underwent their ETT on the same day, due to the working hours of the CM units.

4.9 Conclusion

The Queensland death register recorded no deaths for any of the 297 patients whose charts were audited (concluding in November 2008). However, it must be noted that Australia's other states and territories have their own death registers, and that only the Queensland death register was evaluated. Of the 297 patients, 27 had a further episode of chest pain, one of which was a myocardial infarction. In addition, four had CAs and four had an MPS.

122 (41.07%) patients had entries on the Auslab and/or EDIS computer databases *after* the ETT. The median time period after the ETT was 213.5 days, with an SD of ±218.5 days, and with a maximum period of 814 days.

In response to the question (included in the questionnaire) "How did you rate the whole process of being assessed for your pain?", 85 (73.27%) of the patients rated the process as 5 (very good), 18 (15.51%) rated it as 4 (good), three rated it as 1 (poor), and 3 did not grade the process. It would, therefore, seem that, overall, the patients had a positive view of the process and the service provided.

Chapter 5
CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The audit revealed poor practice and tardiness in respect of following the applicable guidelines, as well as very poor documentation. Despite this, the ETT seemed to be a reasonably safe practice in the specified setting, even in the case of intermediate-risk patients. The ETT helped to identify some patients who needed further investigation for possible IHD.

However, the ETT did not prevent 27 patients from representing to the ED with further episodes of chest pain. The false positive ETTs found were to have been expected, particularly among the younger patients.

5.2 Recommendations

The following recommendations pertain in respect of the current study:

1) ***Education of emergency room doctors***

   Doctors need to be better educated about what constitutes typical ischaemic chest pain, the risk factors of ACS, risk stratification, and the importance of documentation. Specific attention should be given to education of international medical graduates to improve their understanding of the applicable guidelines and in the correct way in which to process risk stratification, as well as to overcome any language and cultural misunderstandings/problems.

2) ***Following of guidelines***

   All medical (from other departments e.g. Medical) and nursing staff should be made aware of the importance of following the appropriate guidelines.

3) ***Use of tick sheets***

   Tick sheets should be used to encourage conformity with the prescribed guidelines and documentation.

4) Consideration of the instituting of critical care pathways

Consideration should be given to the institution of critical care pathways for those patients at high risk for ACS.

5) Continuation and improvement of early ETT

The continuation and improvement of the practice of conducting early ETTs with patients at risk should be carefully considered, with appropriate referral for those with positive and equivocal tests. The continuing use of ETT in selected intermediate-risk patients who have normal ECGs and negative TNI should also receive careful consideration, in order to alleviate the burden on the medical department and to serve as a cost-saving measure.

6) Admittance of patients to the hospital

If any doubt exists, patients should be admitted to the hospital. Such a step needs to be clear in the guidelines, and should be agreed on in conjunction with the medical department.

7) Repetition of audit

The current audit should be repeated after the above changes have been implemented.

REFERENCES

1. Schaer BA, Jenni D, Rickenbacher P, et al. Long-term performance of a simple algorithm for early discharge after ruling out acute coronary syndrome: a prospective multicenter trial. Chest. 2005;127:1364–1370.

2. Eslick GD, Coulshed DS, Talley NJ. The burden of illness of non-cardiac chest pain. Aliment Pharmacol Ther. 2002;6:1217–1223.

3. Cannon CP. Acute coronary syndromes: Risk stratification and initial management. Cardiol Clin. 2005;23(4):401–409.

4. 4821.0.55.001 Cardiovascular disease in Australia: A snapshot, 2004–05. Canberra: Australian Bureau of Statistics.

5. 3303.0 Causes of death, Australia, 2007. Canberra: Australian Bureau of Statistics.

6. Commerford P, Ntsekhe M. Ischaemic heart disease in Africa. How common is it? Will it become more common? Heart. 2008;94:824–825.

7. Steyn K. Heart disease in South Africa. The Heart and Stroke Foundation South Africa. Media data document [cited 2007 Jul]. Available from: http://www.heartfoundation.co.za/docs/heartmonth/HeartDiseaseinSA.pdf

8. Bradshaw D. Unpublished data of the Burden of Disease Research Unit, Medical Research Council, South Africa.

9. Bradshaw D, Groenewald P, Laubscher R, et al. Initial burden of disease estimates for South Africa 2000. S Afr Med J. 2003;92:682–688.

10. Pestana JAX, Steyn K, Leiman A, Hartzenberg GM. The direct and indirect cost of cardiovascular disease in South Africa in 1991. S Afr Med J. 1996;86:679–684.

11. Leeder S, Raymond S, Greenberg H. A Race against time: The challenge of cardiovascular disease in developing economies, New York: Columbia

University, 2004.

12. Norman R, Bradshaw D, Schneider M, Pieterse D, Groenewald P. Revised burden of disease estimates for the comparative risk factor assessment, South Africa 2000. Cape Town: Cape Town Medical Research Council, 2006.

13. Rosamond W, Flegal K, Furie K, et al. Heart disease and stroke statistics 2008 update: A report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation. 2008;117;e25–e146.

14. Boufous S, Kelleher PW, Pain CH, et al. Impact of a chest-pain guideline on clinical decision-making. Med J Aust. 2003 Apr;178:375–380.

15. Lee TH, Rouan GW, Weisberg MC, et.al. Sensitivity of routine clinical criteria for diagnosing myocardial infarction within 24 hours of hospitalization. Ann Intern Med. 1987;106:181–186.

16. Herren KR, Mackway-Jones K, Richards CR, et al. Is it possible to exclude a diagnosis of myocardial damage within six hours of admission to an emergency department? Diagnostic cohort study. Br Med J. 2001;323:1–4.

17. Ramsay G, Podogrodzka M, McClure C, et al. Risk prediction in patients presenting with suspected cardiac pain: The GRACE and TIMI risk scores versus clinical evaluation. QJM. 2007;100:11–18.

18. Goodacre S, Locker T, Morris F, Campbell S. How useful are clinical features in the diagnosis of acute, undifferentiated chest pain? Acad Emerg Med. 2002;9:203–208.

19. Bertrand ME, Simoons ML, Fox KA, et al. Management of acute coronary syndromes in patients presenting without persisting ST-segment elevation. Eur Heart J. 2002; 23:1809–1840.

20. Goodacre SW, Angelini K, Arnold J, et al. Clinical predictors of acute coronary syndromes in patients with undifferentiated chest pain. QJM. 2003;96:893–898.

21. Blatchford O, Capewell S, Murray S, et al. Emergency medical admissions in Glasgow: General practices vary despite adjustment for age, sex and

deprivation. Br J Gen Pract. 1999;49:551–555.

22. Collinson PO, Premachandram S, Hashemi K. Prospective audit of incidence of prognostically important myocardial damage in patients discharged from emergency department. Br Med J. 2000;320:1702–1705.

23. De Araujo Goncalves P, Ferreira J, Aguiar C, et al. TIMI, PURSUIT, and GRACE risk scores: Sustained prognostic value and interaction with revascularization in NSTE–ACS. Eur Heart J. 2005;26:865–872.

24. Diagnosis and management of unstable angina. Canberra: National Health and Medical Research Council, 1998.

25. Nichol G, Walls R, Goldman L, et al. A critical pathway for the management of patients with acute chest pain who are at low risk for myocardial ischaemia: Recommendations and potential impact. Ann Intern Med. 1997;127:996–1005.

26. Lee TH, Cook EF, Weisberg M, et al. Acute chest pain in the emergency room. Identification and examination of low-risk patients. Arch Intern Med. 1985;145:65–69.

27. Thompson PL. Time to move beyond clinical practice guidelines? Med J Aust. 2001;174:211–212.

28. Constantine NA, Philip A, Allan RM, et al. Guidelines for the management of acute coronary syndromes, 2006. Med J Aust suppl. 2006;184:S1–S30.

29. Weiner DA, Manning WJ, Iskandrian AE et al. Advantages and limitations of different stress testing modalities. [cited 2008 April 24] Available from www.uptodate.com

30. Gianrossi R, Detrano R, Mulvihill D, et al. Exercise-induced ST depression in the diagnosis of coronary artery disease: A meta-analysis. Circulation. 1989;80:87.

31. Garber AM, Solomon NA. Cost-effectiveness of alternative test strategies for the diagnosis of coronary artery disease. Ann Intern Med. 1999;130:719.

32. Gibbons RJ, Balady GJ, Bricker JT et al. ACC/AHA 2002 guideline update for exercise testing: Summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to update the 1997 exercise Testing Guidelines). Circulation. 2002;106:1883.

33. Gibbons RJ, Abrams J, Chatterjee K, et al. ACC/AHA 2002 guideline update for the management of patients with chronic stable angina [cited 2006 Aug24]. Available from: ww.acc.org/qualityandscience/clinical/statements.htm.

34. Morise AP, Diamond GA. Comparison of the sensitivity and specificity of exercise electrocardiography in biased and unbiased populations of men and women. Am Heart J. 1995;130:741.

35. Melin JA, Wijns W, Vanbutsele RJ, et al. Alternative diagnostic strategies for coronary artery disease in women: Demonstration of the usefulness and efficiency of probability analysis. Circulation. 1985;71:535.

36. Kafka H, Leach AJ, Fitzgibbon GM. Exercise echocardiography after coronary artery bypass surgery: Correlation with coronary angiography. J Am Coll Cardiol, 1995;25:1019.

37. San Román JA, Vilacosta I, Castillo JA, et al. Selection of the optimal stress test for the diagnosis of coronary artery disease. Heart. 1998;80:370.

38. DePuey EG, Rozanski A. Using gated technetium-99m-sestamibi SPECT to characterize fixed myocardial defects as infarct or artefact. J Nucl Med. 1995;369:52.

39. Tawarahara K, Kurata C, Taguchi T, et al. Exercise testing and thallium-201 emission computed tomography in patients with intraventricular conduction disturbances. Am J Cardiol. 1992;69:97.

40. Strauss HW, Harrison K, Langan JK, et al. Thallium-201 for myocardial imaging: Relation of thallium-201 to regional myocardial perfusion.

Circulation. 1975;51:641.

41. Nielsen AP, Morris KG, Murdock R, et al. Linear relationship between the distribution of thallium-201 and blood flow in ischemic and non-ischemic myocardium during exercise. Circulation. 1980;61:797.

42. Pohost GM, Zir LM, Moore RH, et al. Differentiation of transiently ischemic from infarcted myocardium by serial imaging after a single dose of thallium-201. Circulation. 1977;55:294.

43. Steien S, Aaseth J. Thallium-201 as an agent for myocardial imaging studies. Analyst. 1995 Mar;120(3):779–781.

44. Glover DK, Okada RD. Myocardial kinetics of Tc-MIBI in canine myocardium after dipyridamole. Circulation. 1990;81:628.

45. Okada RD, Glover D, Gaffney T, Williams S. Myocardial kinetics of technetium-99m-hexakis-2-methoxy-2-methylpropyl-isonitrile. Circulation. 1988;77:491-8.

46. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). Circulation. 2007;116:e418-500 [cited 2007 October 23]. Available from: http://circ.ahajournals.org/cgi/reprint/116/17/e418.pdf.

47. Akinpelu D, Gonzalez JM. Pharmacologic stress testing [cited 2009 May 8]. Available from: http://emedicine.medscape.com/article/1827166-overview.

48. Akinboboye OO, Idris O, Chou RL, et al. Absolute quantitation of coronary steal induced by intravenous dipyridamole. J Am Coll Cardiol. 2001 Jan;37:109.

49. Dahlberg S, Leppo J. Risk stratification of the normal perfusion scan: Does normal stress perfusion always mean very low risk? J Nucl Cardiol. 2003 Jan–Feb;10(1):87–91.

50. Skalidis EI, Kochiadakis GE, Koukouraki SI, et al. Myocardial perfusion in patients with permanent ventricular pacing and normal coronary arteries. J Am Coll Cardiol. 2001;37:124.

51. Marcovitz PA, Armstrong WF. Accuracy of Dobutamine stress echocardiography in detecting coronary artery disease. Am J Cardiol. 1992;69:1269-73.

52. Salustri A, Fioretti PM, Pozzoli MM, et al. Dobutamine stress echocardiography: its role in the diagnosis of coronary artery disease. European Heart Journal. 1992;13:70-77.

53. Gibbons RJ. Noninvasive diagnosis and prognosis assessment in chronic coronary artery disease: Stress testing with and without imaging perspective. Circulation: Cardiovascular Imaging. 2008;1:257-269.

54. Cortigiani L, Picano E, Vigna C, et al. Prognostic value of pharmacologic stress echocardiography in patients with left bundle branch block. Am J Med. 2001;110:361.

55. Kim C, Kwok YS, Heagerty P, Redberg R. Pharmacologic stress testing for coronary disease diagnosis: A meta-analysis. Am Heart J. 2001;142:934.

56. Feil H, Siegel ML. Electrocardiographic changes during attacks of angina pectoris. Am J Med Sci. 1928;175:255.

57. Master AM, Oppenheimer ET. A simple exercise tolerance test for circulatory efficiency with standard tables for normal individuals. Am J Med Sci. 1929;177:223.

58. Hill J, Timmis A. ABC of clinical electrocardiography: Exercise tolerance testing. BMJ. 2002;324:1084–1087.

59. Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J. 1973;85:546.

60. Robergs RA, Landwehr R. The surprising history of the ‘HRmax=220−age’ equation. JEP. 2002;5:1-10.

61. Sanchis J, Bodi V, Nunez J, et al. Limitations of clinical history for evaluation of patients with acute chest pain, non-diagnostic electrocardiogram, and normal troponin. Am J Cardiol. 2008;101:613–617.

62. Sanchis J, Bodi V, Nunez J, et al. New risk score for patients with acute chest pain, non-ST-segment deviation, and normal troponin concentrations: A comparison with the TIMI risk score. J Am Coll Cardiol. 2005;45:443–449.

63. Erhardt L, Herlitz J, Bossaert L, et al. Task force on the management of chest pain. Eur Heart J. 2002;23:1153–1176.

64. Antman EM, Cohen M, Bernink PJ, et al. The TIMI risk score for unstable angina / non-ST elevation MI: A method for prognostication and therapeutic decision making. J Am Med Assoc. 2000;284:835–842.

65. Sanchis J, Bodi V, Nunez J, et al. Risk stratification of patients with acute chest pain and normal troponin concentrations. Heart. 2005;91:1013–1018.

66. Lauer MS, Pothier CE, Magid DJ, et al. An externally validated model for predicting long-term survival after exercise treadmill testing in patients with suspected coronary artery disease and a normal electrocardiogram. Ann Intern Med. 2007;147:821–828.

67. deFilippi CR, Rosanio S, Tocchi M, et al. Randomized comparison of a strategy of predischarge coronary angiography versus exercise testing in low- risk patients in a chest pain unit: in-hospital and long-term outcomes. J Am Coll Cardiol. 2001;37:2042–2049.

68. EDIS Diagnosis Statistic Multiple ICD ranges by ICD code from 2007-06-01 to 2008-05-31.

69. Shah PK. New insights into the pathogenesis and prevention of acute coronary syndromes. Am J Cardiol. 1997 Jun 26;79(12B):17–23.

70. Roffi M, Chew DP, Mukherjee D, et al. Platelet glycoprotein IIb/IIIa inhibitors reduce mortality in diabetic patients with non-ST segment elevation acute coronary syndromes. Circulation. 2001;104:2767–2771.

71. Cannon CP, Weintraub WS, Demopoulos LA, et al. Comparison of early invasive and conservative strategies in patients with unstable coronary syndromes treated with the glycoprotein IIb/IIIa inhibitor tirofiban. N Engl J Med. 2001;344(25):1879–1887.

72. Conaway DG, O'Keefe JH, Reid KJ, et al. Frequency of undiagnosed diabetes mellitus in patients with acute coronary syndrome. Am J Cardiol. 2005;96:363–365.

73. Gupta R, Birnbaum, Y, Uretsky, BF. The renal patient with coronary artery disease: Current concepts and dilemmas. J Am Coll Cardiol. 2004;44:1343–1353.

74. K/DOQI clinical practice guidelines for chronic kidney disease: Evaluation, classification, and stratification. Am J Kidney Dis. 2002;39 (2 suppl.):S1–S266.

75. Killip T, Kimball JT. Treatment of myocardial infarction in a coronary care unit: A two year experience with 250 patients. Am J Cardiol. 1967 Oct;20(4):457–464.

76. Leung WC. How to design a questionnaire. BMJ, student ed. 2001 Jun;187–189.

77. Miller CD, Fermann GJ, Lindsell CJ, et al. Initial risk stratification and presenting characteristics of patients with evolving myocardial infarctions. EMJ. 2008;25:492–497.

78. Wrong ACS patients are being referred for angiography. Heartwire [newsletter on the internet of the heart.org] 2008 Feb 13[cited 2008 Feb 13] Available from: www.theheart.org/article/843397.

79. Lee CH, Tan M, Yan AT, et al. Use of cardiac catheterization for non-ST-segment elevation acute coronary syndrome: Reason why physicians choose not to refer their patients. Arch Intern Med. 2008;168:291–296.

APPENDIX

1 Questionnaire

ROCKHAMPTON HEALTH SERVICE DISTRICT

Enquiries to: Sue Davey
Telephone: 07 4920 7044
Facsimile: 07 4920 7249
Email:
Our Ref: «UR_No»

8 July 2008

«First_Name» «Surname»
«ADDRESS_1»
«ADDRESS_2»

Dear Patient

You have visited the Rockhampton Emergency Department and we arranged some investigations for chest pain. You had an exercise stress test carried out on «TEST_DATE».

We are evaluating the outcome of this visit and tests carried out so that we can continue to provide the optimum care for patients.

Will it be possible for you to answer the following questions and send it back in the enclosed envelope on or before 22 January 2009?

If you have any questions in relation to this please contact Sue Davey on 4920 7044.

Yours faithfully

Dr Henk Siglé
Senior Medical Officer
Emergency Department
Rockhampton Hospital

Questions:

- Have you had any chest pain or heart problems since this last visit to the Emergency Department?

Yes/No

If yes: did you have a heart attack/ angiogram/myocardial perfusion scan/other _____

- How did you rate the whole process of being assessed for your pain?

Excellent 5 4 3 2 1 Poor (*with 5 being very good and positive and one being poor and negative)*

Once again, thank you for your help in completing these questions. This feedback is very helpful for us in improving care of patients attending the department in the future.

Regards,

Dr Henk Siglé
Emergency Department

Risk scores

PURSUIT
(0–18)

Age, separate points for enrolment diagnosis	
Decade [UA (MI)]	
50	8 (11)
60	9 (12)
70	11 (13)
80	12 (14)
Gender	
Male	1
Female	0
Worst CCS class in previous 6 weeks	
No angina or CCS I/II	0
CCS III/IV	2
Signs of heart failure	2
ST depression on presenting ECG	1

TIMI
(0–7)

Age 65 years	1
≥ 3 risk factors for CAD	1
Use of ASA (last 7 days)	1
Known CAD (stenosis 50%)	1
> 1 episode rest angina in 24 hrs	1
ST segment deviation	1
Elevated cardiac markers	1

GRACE
(0–258)

Age (years)	
< 40	0
40–49	18
50–59	36
60–69	55
70–79	73
≥ 80	91
Heart rate (bpm)	
< 70	0
70–89	7
90–109	13
110–149	23
150–199	36
> 200	46
Systolic BP (mmHg)	
< 80	63
80–99	58
100–119	47

120–139	37
140–159	26
160–199	11
> 200	0
Creatinine (mg/dl)	
0–0.39	2
0.4–0.79	5
0.8–1.19	8
1.2–1.59	11
1.6–1.99	14
2–3.99	23
> 4	31
Killip class	
Class I	0
Class II	21
Class III	43
Class IV	64
Cardiac arrest at admission	43
Elevated cardiac markers	15
ST segment deviation	30

*P de Araujo Conçalves et al. “TIMI, PURSUIT, and GRACE risk scores: Sustained prognostic value and interaction with revascularization” in *NSTEACS Eur Heart J* 2005;26:865−872.

UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: shuretta.thomas@uct.ac.za

8 December 2008

REC REF: 473/2008

Dr H Sigle
Emergency Medicine
Rockhampton Hospital

Dear Dr Sigle

PROJECT TITLE: USE OF STRESS ECG IN EMERGENCY DEPARTMENT TO ASSESS LOW RISK PATIENTS WITH SUSPECTED CORONARY SYNDROME

Thank you for submitting your study to the Research Ethics Committee for review.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 10 December 2009.

Please submit an annual progress report if the research continues beyond the expiry date. Please submit a brief summary of findings if you complete the study within the approval period so that we can close our file.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

Wesley Stanley

pp **PROFESSOR M BLOCKMAN**
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-

SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

lemjedi

Queensland Government

Queensland **Health**

CENTRAL QUEENSLAND HEALTH SERVICE DISTRICT

Enquiries to: Peter Thompson
Telephone: 07 4920 7570
Facsimile: 07 4920 7249
Email:
Our Ref:

10 August 2008

To Whom It May Concern:

Dr HM Siglé has permission to audit the charts of patients who had Stress ECG's via the Emergency Department at the Rockhampton Base Hospital as well as to conduct a questionnaire in relation to these Stress ECG's.

This audit is part of a dissertation for the degree MPhil (EM) from the University of Cape Town.

Yours sincerely

Peter Thompson
Director - Emergency Department
Rockhampton Base Hospital
Tel: 07 4920 7570
Mob: 0438 716 689 / 0488 766 400
E mail: peter_thompson@health.qld.gov.au

Office
Director of Emergency Department
Central Queensland Health Service District

Postal
Rockhampton Hospital
Canning Street
Rockhampton Q 4700

Phone
4920 7570

Fax
4920 7249