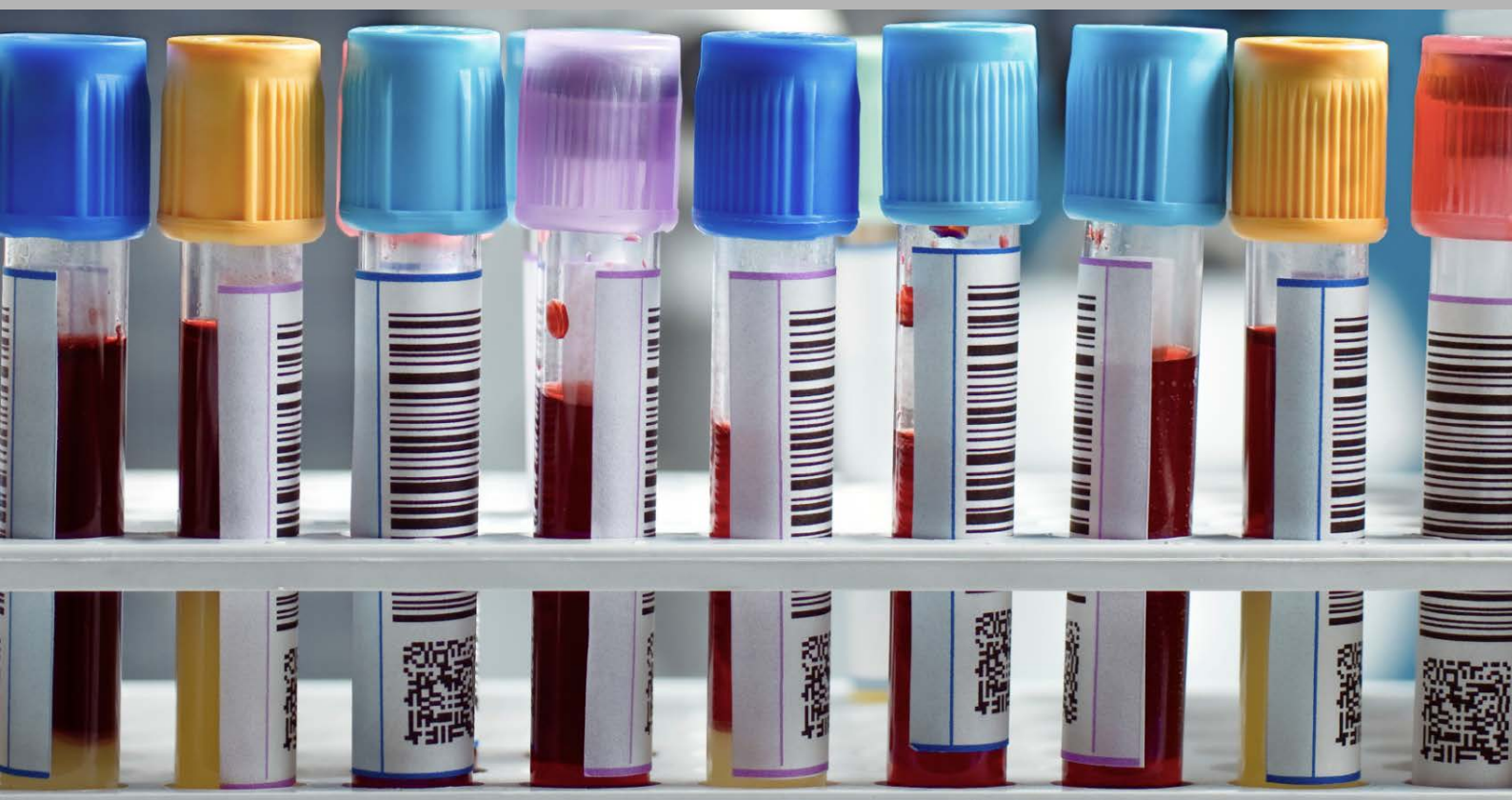
AUSTRALIAN INSTITUTE OF HEALTH INNOVATION

MACQUARIE University

Examination of variation in hospital pathology investigations by Diagnosis-Related Groups and associations with outcomes and costs



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Preamble

This report is produced by the Centre for Health Systems and Safety Research (CHSSR) funded by an Australian Government Department of Health Quality Use of Pathology Program (QUPP) grant.

The QUPP grant was awarded when CHSSR was part of the Faculty of Medicine at UNSW Australia (The University of New South Wales) and much of the work reported herein was conducted by CHSSR within UNSW Australia.

CHSSR was affiliated with the Faculty of Medicine and Health Sciences at Macquarie University starting on 3rd November 2014 and the report content was finalised by CHSSR within Macquarie University.

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SECTION I: EXECUTIVE SUMMARY

The National Health Reform Agreement, signed by all Australian governments in August 2011, commits to funding public hospitals using Activity-Based Funding (ABF) where practicable. Diagnosis Related Groups (DRGs) enable hospitals to be paid for the number and mix of patients they treat. This is achieved by reducing a large number of individual hospital patients into manageable and meaningful groups. They can then be used for comparisons across different settings to measure efficiency and effectiveness, as well as monitor variation in the care that patients receive. DRGs may also provide incentive to stimulate productivity (e.g. patient throughput, reduced wait times, rational test ordering etc.) and moderate growth in hospital costs. Public hospital inpatient and emergency services across NSW have been funded using ABF with Diagnosis-Related Group (DRG) and Urgency-Related Group (URG) codes since July 2012.

The project is a collaboration between the Centre for Health Systems and Safety Research (CHSSR), a part of the Australian Institute of Health Innovation (AIHI), and South Eastern Area Laboratory Services (SEALS).[1] That collaboration was supported by a previous Quality Use of Pathology Program (QUPP) grant (2011–2012) and led to the development of an empirically-derived benefits realisation framework based on data linkage across hospital databases.

PROJECT AIM

This project will utilise key performance measures from the benefits realisation framework to:

- Examine the use of Diagnosis-Related Group (DRG) and International Classification of Disease (ICD) codes to identify profiles of pathology requesting and compare performance across hospital and clinician levels.
- Undertake statistical and economic modelling to establish the relationship between the pathology requesting profiles and patient outcomes (e.g. length of stay in hospital, phlebotomy episodes and rates of hospital re-admission); and resource utilisation.

PROJECT SETTING

The study was conducted at a group of six hospitals serviced by a single pathology service that provides comprehensive biomedical laboratory services. Two hospitals were metropolitan general hospitals, two were specialist metropolitan hospitals (a women's hospital and a children's hospital), one hospital was a regional general hospital and one was a rural general hospital. The hospitals had a combined total of over 2,200 beds.

A Cerner Powerchart Electronic Medical Record (EMR) system, which enables electronic creation of pathology test orders, was implemented across the six hospitals. In 2013, approximately 80% of pathology test orders across the six study hospitals were created using the EMR system.

LITERATURE REVIEW

A literature review was undertaken to investigate how DRGs (or related casemix systems) have been used to evaluate the use of pathology laboratory testing. Forty-two relevant articles were identified from a search of EMBASE, Medline and CINAHL. The majority of studies (79%) were conducted in the USA. Three studies (7%) were conducted in Australia. The studies were abstracted and summarised to identify the following key pathology laboratory categories: Appropriateness (e.g. test ordering compliance with guidelines) (n=5); Cost-control (e.g. lab costs per DRG) (n=27); Patient outcomes (e.g. Length of Stay) (n=28); and Utilisation (e.g. test utilisation rates per patient) (n=25).

KEY FINDINGS

TEST VOLUME UTILISATION

When the test volume utilisation is adjusted for hospital, year, casemix (DRG), patient age and sex, the test utilisation generally increased each year between 2008 and 2011. The adjusted rate was higher in 2012 compared to 2011, for Hospitals A, D and F, but not Hospital E. There was a significant reduction in the adjusted mean rate of tests per patient day, from 2012 to 2013, at Hospitals D and E (approximately 0.4 fewer tests per patient day). There was no significant difference in the rate, from 2012 to 2013, at Hospitals A and F.

VARIATION BETWEEN CLINICIANS

When focusing on patients who were allocated to the 'Chest Pain' DRG, and comparing the variation between clinicians, Hospital D had the lowest median number of pathology tests ordered per patient day, but had the greatest variation between clinicians. Hospital F had the smallest variation between clinicians.

REPEAT TESTING

Overall repeat Electrolytes, Urea, Creatinine (EUC) test rates within 24 hours of the previous test were similar at all study hospitals. This pattern was also found when focusing on patients admitted with the 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' DRG, but for the 'Chest Pain' DRG, repeat EUC test rates within 24 hours varied considerably between the four study hospitals. The repeat EUC test rate within 24 hours exceeded 20% at Hospital A, but was approximately 5% at Hospital D. A similar pattern was found for repeat Full Blood Count (FBC) tests.

TURN-AROUND TIMES

The Turn-Around Times (TATs) were compared for the Top-10 pathology tests ordered for inpatients registered with the 'Chest Pain' DRG and matching populations within the ED (some of whom were admitted as inpatients, and others whose treatment was completed within the ED). Overall, pathology tests ordered for ED patients whose treatment was completed in the ED were processed the quickest, with a median TAT of 49 minutes; the TAT was 52 minutes for ED patients who were eventually admitted and 60 minutes for inpatients. Similarly, the overall variability, as indicated by the Inter-Quartile Range (IQR), was smallest for ED patients whose treatment was completed in the ED (IQR=34 minutes); second smallest for ED patients

who were eventually admitted (IQR=40 minutes); and greatest for inpatients (IQR=53 minutes). The same pattern, for both median TATs and variability, was evident for almost all Top-10 tests considered in the analysis.

DEMAND MANAGEMENT IN THE ED

Patients presenting with digestive system illnesses accounted for the highest proportion of patients (25%) who had a C-Reactive Protein (CRP) test ordered in the first test order episode. Patients presenting with neurological illnesses accounted for the highest proportion of patients (23%) who had a Creatine Kinase (CK) test ordered in the first test order episode.

EUC and FBC tests were consistently the most frequently ordered tests in the first test order episode for patients located in the acute/resuscitation area for all ED presentations with circulatory, digestive, respiratory, neurological illnesses and system infection/parasites (the Top-5 MDB categories with most ED presentations).

CARESET UTILISATION

Out of 289,417 tests, 34,008 were ordered as part of a Careset (also known as 'Order Sets'), accounting for 11.8% of tests. 'Blood Group and Antibody Screen', containing Blood Group and Antibody Screen, BBT History and Anti-D Antibody, was the most frequently ordered Careset, ordered 4,441 times and accounting for 51.2% of all Caresets ordered. 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' was the inpatient DRG with the most number of Caresets ordered at 1,427 (14.2%). However, there were several DRGs where a greater proportion of tests were ordered using Caresets, including 'Neonate, AdmWt >2499g W/O Significant OR Procs W/O Problem' with 40.4% of tests ordered as a Careset and 'Red Blood Cell Disorders W/O Cat or Sev CC' with 39.4% of tests ordered as a Careset.

ED LOS

Multilevel modelling analyses, which do not constitute evidence for causation, indicated that ED patients who were eventually admitted as inpatients were estimated to have an additional 158.1 minutes length of stay in the ED if any pathology tests were ordered during their ED presentation. For ED patients whose treatment was completed within the ED, they were estimated to have an additional 98.5 minutes length of stay in the ED if any pathology tests were ordered. The utilisation of any imaging procedures during the ED presentation were estimated to increase ED LOS by 37.7 minutes for patients whose treatment was completed within the ED, but reduce the ED LOS by 44.6 minutes for patients who were eventually admitted.

The impact of pathology testing on ED LOS differed according to the laboratory department involved. The impact was greater for pathology tests conducted in the Clinical Chemistry department (an estimated increase of 112.0 minutes in ED LOS) than for tests conducted in Haematology (an estimated increase of 46.1 minutes in ED LOS) and Microbiology departments (an estimated increase of 63.0 minutes in ED LOS).

COST PROFILE IN ED

There was a positive correlation between the mean number of pathology tests and reimbursement in AUD units for ED presentations that did not result in a hospital admission (Pearson r =.76). There was also a strong positive correlation between ED LOS and AUD reimbursement for patients who were not admitted (Pearson r =.76, by coincidence, the same correlation as for mean number of pathology tests), but the correlation was negative for patients who were admitted as hospital inpatients (Pearson r =-.33).

SECTION II: GLOSSARY

Glossary of general terms	
95% CIs	95% Confidence Intervals
ABF	Activity Based Funding
ACEM	Australasian College for Emergency Medicine
AIHI	Australian Institute of Health Innovation
Cat	Catastrophic
CC	Complication or Comorbidity
CCL	Cerner Command Language
Cerner FirstNet	Electronic Medical Record interface used in EDs
Cerner Discern Explorer	Interface for Cerner CCL
Cerner PowerChart	Electronic Medical Record system used at the study hospitals
CHSSR	Centre for Health Systems and Safety Research
CINAHL	Cumulative Index to Nursing and Allied Health Literature database
CPOE	Computerised Provider Order Entry
CSR	Central Specimen Reception
CSV	Comma-separated Values file
DRG	Diagnosis-Related Group
ED	Emergency Department
ED LOS	Emergency Department Length of Stay
EMBASE	Excerpta Medica dataBASE database
EMR	Electronic Medical Record
GEE	Generalised Estimating Equation modelling
IQR	Inter-Quartile Range
ISS	Integrated Software Solutions
LIS	Laboratory Information System
LOS	Length of Stay
MDB	Major Diagnostic Block
MEDLINE	Medical Literature Analysis and Retrieval System Online database
MeSH	Medical Subject Headings
NEAT	National Emergency Access Target
NEP	National Efficiency Price
NWAU	National Weighted Activity Unit
NWAU(13)	National Weighted Activity Unit for 2013-2014 financial year
PAS	Patient Administration System
PPS	Prospective Payment System
Procs	Procedure(s)
QUPP	Quality Use of Pathology Program
RCPA	Royal College of Pathologists of Australasia
RIS	Radiology Information System
RVU	Relative-Value Units
SAS	Statistical Analysis System software
SEALS	South Eastern Area Laboratory Services
Sev	Severe
SPSS	Statistical Package for the Social Sciences software
TAT	Turn-Around time
URG	Urgency-Related Group
Vent	Ventilation
W/	With
W/O	Without

Glossary of pathology tests	
BBT History and Anti-D antibody	Blood Bank Test History and Anti-D antibody
BLOOD GAS	Blood gases
CA MG PHOS	Calcium, magnesium, phosphate
CK	Creatine Kinase
CKMB	Creatine Kinase MB isoenzyme
CRP	C-Reactive Protein
D-Dimer LIA	D-Dimer Latex Immuno Assay
ESR	Erythrocyte Sedimentation Rate
EUC	Electrolytes, Urea, Creatinine
FBC	Full Blood Count (Automated Differential)
Glucose	Glucose
LFT	Liver function test
Lipase	Lipase
Protein EPG	Serum Protein Electrophoresis
PT	Prothrombin time
INR	International normalised ratio
APTT	Activated partial thromboplastin time
TnT	Troponin I and Troponin T
TSH	Thyroid Stimulating Hormone

SECTION III: CONTEXT AND INTRODUCTION

ACTIVITY-BASED FUNDING

Over the last three decades there has been considerable growth in the number of requests for pathology and medical imaging services. Medicare-funded laboratory tests in Australia increased by 54% between the period 2000-2001 to 2007-2008.[2] Improvements in the quality of pathology requesting rely upon good data regarding current practices and the identification of areas in need of greater attention and support. There is currently little meaningful data about variation in the use of pathology investigations by patient diagnostic groups. Diagnosis-Related Groups (DRGs) provide a basis to compare profiles of pathology requesting for similar patient groups across hospitals, specialties and by clinician.

DRGs were developed out of Yale University in the USA in the 1970s with the aim of defining and measuring hospital performance.[3] DRGs developed into a system which sought to pay hospitals based on the premise that money should follow the patient – a model that is often referenced as Activity-Based Funding (ABF).[4] DRGs have also been used as a means of monitoring care, improving transparency and improving efficiency.[5] They enable hospitals to get paid for the number and mix of patients they treat. DRGs achieve this by reducing a large variety of individual hospital patient characteristics into manageable and meaningful groups that can then be used to make comparisons across different settings, measure efficiency and effectiveness, as well as monitor variation in the care that patients receive.[6] These benefits may also provide incentive to stimulate productivity (e.g. patient throughput, reduced wait times, rational test ordering etc.) and moderate growth in hospital costs.[4] In Australia, the National Health Reform Agreement, signed by all Australian governments in August 2011, commits to funding public hospitals using ABF (with DRGs) where practicable.[6]

This project is based upon an extensive data linkage exercise using data from the pathology service along with key hospital data sources to examine the DRG profile of pathology requesting and their effect on key clinical outcomes (e.g. length of stay). The project will undertake comparative (across hospital and clinician level) analyses covering six hospitals (including metropolitan and regional hospitals) in two Local Health Districts and a Children's Hospital Network.

The project builds upon a research collaboration between the Centre for Health Systems and Safety Research (CHSSR), part of the Australian Institute of Health Innovation (AIHI) and South Eastern Area Laboratory Services (SEALS). This collaboration was supported by a previous Quality Use of Pathology Program (QUPP) grant (2011 – 2012) and led to the development of an empirically-derived benefits realisation framework based on data linkage across hospital databases.

PROJECT AIM

This project will utilise key performance measures from the benefits realisation framework to:

- Examine the use of Diagnosis-Related Group (DRG) and International Classification of Disease

(ICD) codes to identify profiles of pathology requesting and compare performance across hospital and clinician levels.

- Undertake statistical and economic modelling to establish the relationship between the pathology requesting profiles and patient outcomes (e.g. length of stay in hospital, phlebotomy episodes and rates of hospital re-admission); and resource utilisation.

The project will allow comparisons that can be used by hospitals to assess their own performance while using DRGs to account for patient casemix and other potentially confounding variables. The project will assess associations between patterns of pathology utilisation, clinical outcomes and resource utilisation. It will also identify areas where greater attention needs to be placed on improving the utilisation of pathology services.

The research collaboration between CHSSR, SEALS and the South Eastern Sydney and Illawarra Shoalhaven Local Health Districts and Sydney Children's Hospitals Network has included large scale studies that were funded by the Department of Health, Quality Use of Pathology Program.[1] That work included the creation and extensive utilisation of an enriched dataset using sophisticated data linkage methods to incorporate some 2.8 million pathology tests (from the Laboratory Information System [LIS]), 147,280 inpatient admissions (from the Patient Administration System [PAS]) and 176,015 Emergency Department (ED) presentations (from the Emergency Department information system) across six hospitals. That foundational work has produced major evidence about key facets of laboratory test management (e.g. quality and safety of laboratory processes), clinical performance (e.g. test order appropriateness) and patient outcome (ED length of stay).

This project extends that work by linking data from the Radiology Information System (RIS), PAS, ED information system and LIS to create an enriched dataset. enabling the application of advanced statistical techniques involving cross-classified multilevel models to examine correlations within each study site and each calendar year, adjusting for potential confounding factors, such as patient age, triage category and day and time of presentation.[7]

KEY PERFORMANCE INDICATORS

EMERGENCY DEPARTMENT LENGTH OF STAY (ED LOS)

Defined as the amount of time a patient remains in ED from arrival or triage to when they leave the ED, this indicator can be used to help understand the impact that factors associated with pathology testing (or medical imaging tests) have on a patient's LOS in the ED. Quantifying benefits, in patient-experience terms, can inform resource-allocation strategies in the hospital.

TEST APPROPRIATENESS

The term 'inappropriate testing' is generally used to refer to the ordering of tests without a clear clinical indication, or tests performed at the wrong time or too frequently to be of value in diagnosis or clinical management, contradicting evidence-based guidelines and expert consensus.[8] While there are many

pathology tests that are conducted repeatedly in order to monitor a condition or treatment, when a test is ordered again before the recommended time frame for a repeat test there is a high likelihood that it will be redundant and will provide no additional information.[9,10]

TEST VOLUMES

This measure can be defined as the total number of tests ordered for a given period measured through a variety of methods such as per test order episode, per patient admission, per Diagnosis-related Group (DRG), per patient admission and per specific test type (e.g. Troponin). Assessing test volume using a variety of metrics (described above) allows for a comprehensive analysis of test utilisation in the pathology service. For example, assessing test volume per test order episode informs whether changes that make test ordering more accessible (i.e., electronic ordering) are associated with over-ordering; assessing test volume per patient admission per DRG allows test volume assessments to control for the type, severity and complexity of the patients' condition.

TURN-AROUND TIMES (TAT)

Total Turn-Around Time (TAT) is measured from when the specimen is collected from the patient to when a result is available to the clinician. Laboratory TAT is the time taken by the laboratory to complete the testing process (from when the specimen arrives in the CSR to when a result is available to the clinician). It is also possible to analyse the CSR Data Entry TAT (from receipt of the specimen at CSR to when the specimen is ready to leave CSR for processing and analysis). TAT can be affected by a number of factors including the type of test being ordered and transportation requirements.

SECTION IV: LITERATURE REVIEW ON THE USE OF DRGs IN THE EVALUATION OF PATHOLOGY LABORATORY ACTIVITY

AIM

The aim of this section is to report on a literature review into how DRGs (or related casemix systems) have been used to evaluate the use of pathology laboratory testing.

SEARCH STRATEGY

The literature review was based on a search of MEDLINE, CINAHL and EMBASE keywords and MeSH terms associated with hospitals, DRGs, casemix and laboratories for the years 1980 to 2013. Quantitative papers were included if they were written in English and used DRGs to monitor laboratory testing. An initial title and abstract review identified those papers to be read in full.

RESULTS

Database searches identified a total of 1189 articles, from EMBASE (n=630), Medline (n=454) and CINAHL (n=105), of which 310 were identified as duplicates. Our Title/Abstract screening of the articles reduced the number of articles to 53, of which a further 11 were excluded following full text review, leaving 42 articles.

Information about the title, aim, setting, method and measurement indicator for each of the articles were abstracted and summarised to identify the following key pathology laboratory categories: Appropriateness (e.g. test ordering compliance with guidelines), Cost-control (e.g. lab costs per DRG), Patient outcomes (e.g. Length of Stay or in-hospital mortality) and Utilisation (e.g. test utilisation rates per patient).

Twenty-seven (64%) of the included studies were published pre-2000, with ten (24%) published in the period leading up to (and including) 1990. The great majority of studies (79%) were conducted in the USA. Three studies (7%) were conducted in Australia.

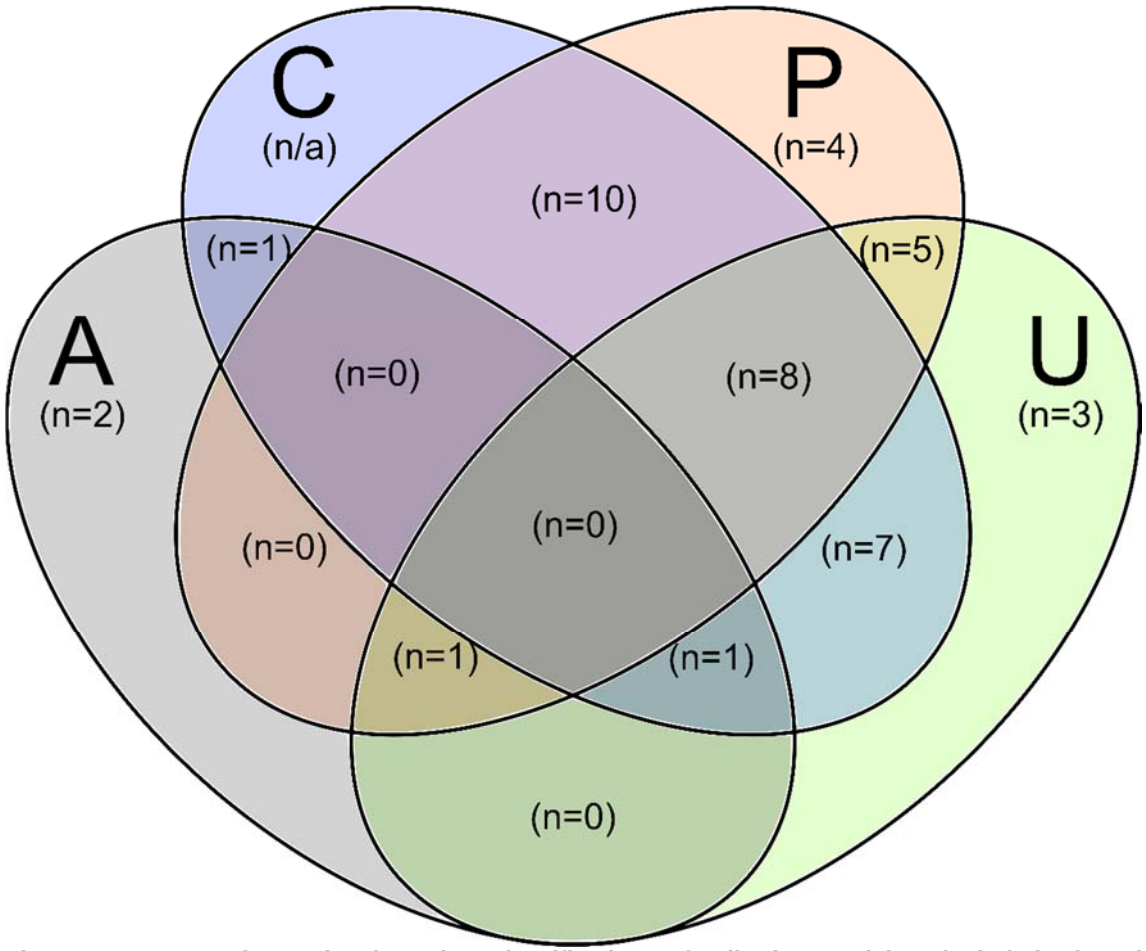

Figure 1. Venn chart showing the classification of all the 'Articles included' (N=42). A = Appropriateness; C = Cost-control; P = Patient Outcomes; U = Utilisation.

All of the five studies that assessed appropriateness were undertaken in the USA. Two studies considered the role of guidelines on the appropriateness of laboratory test ordering. One looked at the proportion of patients for whom pathology tests were ordered using one of three recommended order sets.[11] The other conducted an appropriateness review, using a chart review method, of lab tests ordered (or tests that should have been ordered) compared to guidelines.[12] A third study considered the frequency of abnormal test results that led to a change in treatment/diagnosis or follow-up tests.[13] One study considered the ratio of patients who received at least one laboratory test, to the average number of laboratory tests per patient, before and after the introduction of a prospective payment system (PPS), suggesting that a higher ratio possibly represented more appropriate care.[14] The final study looked at assessment dimensions for lab tests.[15]

The second area of analysis was cost-control. Twenty-seven studies, conducted in the USA, Australia, Italy, Japan, Israel and Ireland, considered this topic. Twenty studies examined laboratory costs (overall and/or per DRG and/or per patient and/or per day).[15-34] Six studies looked at hospital costs (overall and/or per patient and/or day).[28,35-39] One study looked at the correlation between hospital policy on number of daily Creatine Kinase MB isoenzyme (CKMB) batched runs and laboratory costs.[34] One study estimated the money saved from an intervention, based on the reductions in test volume and average per test cost.[12]

Another study examined the percentage of patient-bed-day costs accounted for by laboratory tests.[24] Finally, one study conducted a cost-benefit analysis of outsourced laboratory services.[40]

Twenty-eight studies examined patient outcomes. These studies were conducted in the USA, Australia, Israel, Austria, Japan and Ireland. Twenty-six of these studies considered the mean/median/mode hospital/ward length of stay (LOS) per patient and/or per DRG.[14,16-21,23,25,28,29,32-38,41-49] Seven studies considered in-hospital mortality rate (overall or per DRG).[14,18,25,28,32,37,49] One study examined the mortality rate within 30 days of patient admission[50] and another the mortality rate within six months of discharge.[27] Three studies looked at hospital re-admission rates within seven days,[38] within 28 days,[27] and within 30 days[28] of discharge. One study analysed the correlation between hospital policy on the number of daily CKMB batched runs and hospital LOS.[34] Another study considered the mean number of blood draws per patient, while also looking at the mean blood volume drawn/lost (estimated) per patient.[49] One study considered exposure to further blood draws and lab tests,[38] and another analysed patient destination after discharge.[14]

Twenty-five studies examined procedure utilisation rates. These studies were conducted in Australia, Austria, Canada, Italy, Japan, Spain and the USA. Nineteen studies examined test utilisation rate/mean or median lab test volume per patient, in 'raw' units.[12,14,17,21-23,25,26,28,30,31,35,38-41,45,47,51] Three studies considered test utilisation rate/mean lab test volume per patient, in relative value units (RVUs).[23,46,52] Also studied were the number of test panels ordered and individual test results received per admission;[42] the actual minus expected measure of test utilisation, overall and per-patient excess test rate.[12] Another study investigated both the test volume per bed-day/patient-day and the percentage of lab activity accounted for by Top-20 most frequently ordered laboratory tests.[24] One study compared the mean number of laboratory tests between two clinical pathways[19] and a final one considered the test utilisation rate/mean lab test volume per patient admission and per patient day.[36]

Table 1. Descriptions of the final selection of articles that met all the inclusion criteria, including the authors, year of publication, country where the study took place, the types of outcome measures utilised and a description of the outcome measure and relevant comparisons.

Authors	Year	Country	Measures
Aziz *et al.*[16]	2012	Ireland	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Lopez-Castroman *et al.*[30]	2012	Spain	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Sato & Fushimi[46]	2012	Japan	(Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean lab test volume per patient (in Relative-Value Units - RVUs)
Haschke-Becher *et al.*[25]	2009	Austria	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) In-hospital mortality rate (overall or per DRG) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Khaliq *et al.*[28]	2007	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Cost-control) Hospital costs (overall and/or per patient and/or day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) In-hospital mortality rate (overall or per DRG) (Patient Outcome) Hospital re-admission within 30 days of discharge (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Cutler *et al.*[22]	2007	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)
Petersen *et al.*[38]	2005	USA	(Cost-control) Hospital costs (overall and/or per patient and/or day) (Cost-control) Hospital costs (overall and/or per patient and/or day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) Hospital re-admission within 7 days of discharge (Patient Outcome) Exposure to further blood draws and lab tests (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)
Angle *et al.*[35]	2004	USA	(Cost-control) Hospital costs (overall and/or per patient and/or day) (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Dorafshar *et al.*[37]	2004	USA	(Cost-control) Hospital costs (overall and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) In-hospital mortality rate (overall or per DRG)
Brimhall *et al.*[20]	2003	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Kamal *et al.*[11]	2003	USA	(Appropriateness) % of patients for which pathology tests were ordered using one of three recommended order sets (ADM ACUTE MI, ADM ANGINA/ROMI/CAD and ROMI SECONDARY DX)

Authors	Year	Country	Measures
Van Rhee *et al.*[32]	2002	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) In-hospital mortality rate (overall or per DRG)
Barenfanger *et al.*[17]	2002	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Board & Kaplan[19]	2000	Australia	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Plapp *et al.*[39]	2000	USA	(Cost-control) Hospital costs (overall and/or per patient and/or day) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Jha *et al.*[26]	1998	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Kerr *et al.*[27]	1998	Australia	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mortality within 6 months of discharge (Patient Outcome) Hospital re-admission within 28 days and 6 months of discharge
Maor *et al.*[50]	1998	Israel	(Patient Outcome) Mortality within 30 days of patient admission
Racine *et al.*[45]	1998	USA	(Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Wu & Clive[34]	1997	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) Correlation between hospital policy on number of daily CKMB batched runs and Hospital LOS
Zimmerman *et al.*[49]	1997	USA	(Patient Outcome) In-hospital mortality rate (overall or per DRG) (Patient Outcome) Mean number of blood draws per patient (Patient Outcome) Mean blood volume drawn/lost (estimated) per patient
Katz *et al.*[52]	1996	USA Canada	(Utilisation) Test utilisation rate/mean lab test volume per patient (in Relative-Value Units - RVUs)
Barie *et al.*[18]	1996	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Patient Outcome) in-hospital mortality rate (overall or per DRG)
Bowers[40]	1995	USA	(Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)
Mozes *et al.*[44]	1994	USA	(Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)

Authors	Year	Country	Measures
Edwards & Lapsley[24]	1993	Australia	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Utilisation) Test volume per bed-day/patient day (Utilisation) % of lab activity accounted for by Top-20 laboratory tests
Litwin *et al.*[29]	1993	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Lipsitz *et al.*[51]	1993	USA	(Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Bunton & Gaede[13]	1992	USA	(Appropriateness) Used chart review to compare the frequency/proportion of ABNORMAL lab test results, for different test types, that led to a work-up, follow-up tests/consults, a change in treatment, a new diagnosis, or no action (for 24 common DRGs)
McMahon *et al.*[48]	1992	USA	(Cost-control) Hospital costs (overall and/or per patient and/or per day (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Cristina *et al.*[21]	1991	Italy	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units)
Steiner *et al.*[31]	1991	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)
Broyles[36]	1990	USA	(Cost-control) Hospital costs (overall and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean lab test volume per patient admission and per patient day
Davidoff *et al.*[42]	1989	USA	(Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Number of Test panels ordered and individual test results received per admission
Goldman *et al.*[43]	1989	USA	(Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Gortmaker *et al.*[12]	1988	USA	(Appropriateness) Appropriateness review, using chart review method, of lab tests ordered (or tests that should have been ordered) compared to guidelines (Cost-control) Extrapolation of money saved from intervention based on the reductions in test volume and average per test cost (Utilisation) Test utilisation rate/mean or median lab test volume per patient (in 'raw' units) (Utilisation) Actual-minus-expected measure of test utilisation (overall and per-patient excess test rate)
Sloan *et al.*[47]	1988	USA	(Patient Outcome) Mean/Median/Mode LOS (per patient and/or per DRG) (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)

Authors	Year	Country	Measures
Long *et al.*[14]	1987	USA	(Appropriateness) Comparison pre-post the introduction of Prospective Payment system (PPS), of the ratio of patients who received at least one laboratory test to the average number of laboratory tests per patient (a higher ratio possibly reflecting more appropriate care) (Patient Outcome) Mortality within hospital stay (i.e. discharged dead) (Patient Outcome) Patient destination after hospital discharge (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Proportion of patients with at least one laboratory test (Utilisation) Test utilisation rate/mean lab test volume per patient (in 'raw' units)
Ferraro[15]	1986	USA	(Appropriateness) Description of assessment dimensions for laboratory tests (Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day)
Wachtel *et al.*[33]	1986	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG)
Becker & Sloan[41]	1983	USA	(Patient Outcome) Mean/ Median/ Mode hospital LOS (per patient and/or per DRG) (Utilisation) Test utilisation rate/ mean or median lab test volume per patient (in 'raw' units)
DesHarnais *et al.*[23]	1983	USA	(Cost-control) Laboratory costs (overall and/or per DRG and/or per patient and/or per day) (Patient Outcome) Mean/Median/Mode hospital length of stay (LOS) (per patient and/or per DRG) (Utilisation) Test utilisation rate/mean lab test volume per patient (Utilisation) Test utilisation rate/mean lab test volume per patient (in Relative-Value Units - RVUs)

SECTION V: METHODS

STUDY SETTING

The project was undertaken across two Local Health Districts and one Children's Hospital Network in New South Wales, covering a resident population of around 1.2 million people.[53] The focus was on a group of six hospitals serviced by a single fully accredited pathology laboratory service, which provides comprehensive biomedical laboratory services including the following laboratory specialties: Anatomical Pathology, Blood Bank, Clinical Chemistry, Microbiology, Endocrinology, Haematology, Molecular Genetics and Immunology. In the 2013-2014 financial year (1st July-30th June), the pathology service employed over 800 staff and processed approximately 6.2 million test sets (leading to 38.8 million test results).

During the initial implementation, the Electronic Medical Record (EMR), which enables clinicians to create electronic orders, was based on the Cerner PowerChart system, Version 2007.16 and became available at Hospitals A, B and C on 26 October 2009; Hospital D on 29 June 2009, Hospital E on 1 October 2008 and Hospital F on 9 March 2009. In May 2011, the EMR was upgraded to Cerner PowerChart system, Version 2010.02.16, and in May 2013 to Cerner PowerChart system, Version, 2012.01.14. The LIS in Hospitals A, B, C and E is Integrated Software Solutions (ISS) Omnilab v9.4.2 SR10 while in Hospitals D and F the LIS is ISS Omnilab v9.5.2 SR26. Table 2 shows the number of available beds, the number of pathology tests and number of patients who had pathology tests, at each of the six study hospitals for the month of December 2013. The three large metropolitan general hospitals (A, E and F) accounted for the bulk of inpatient admissions, ED presentations and pathology testing. The two specialist hospitals, (B and C) and the regional hospital (D), accounted for the smallest proportion of inpatient admissions, ED presentations and pathology testing.

Table 2. The number of beds, inpatient admissions, ED presentations, patients who had at least one pathology test and the total number of pathology tests at each of the six study hospitals for the month of December 2013.

Hospital	Available Beds	Inpatient Admissions	ED Presentations	No. of Patients who had tests[a]	No. of Tests[a]
A	538	3,633	4,880	5,723	89,922
B	161	1,297	n/a	2,272	16,514
C	153	1,452	3,168	1,937	30,427
D	190	1,528	3,452	2,028	25,959
E	647	4,695	6,013	6,725	109,743
F	540	4,178	5,424	5,485	89,260
Total	2,229	16,783	22,937	24,170	361,825

[a] Includes outpatients and referred tests

The number and proportion of tests that were ordered electronically (using the EMR) for each of the six hospitals during each year between 2008 and 2013 (excluding outpatients and referred tests), are shown in

Table 3. In 2009, 48.96% of all tests ordered across all sites were ordered electronically, the remainder were paper orders. After the introduction of EMR at Hospitals A, B and C in October 2009, the overall proportion of tests ordered with EMR in 2010 increased to 79.35%, peaking at 81.03% in 2012.

Table 3. The volume and proportion of electronically-ordered (EMR) tests at the six study hospitals. Outpatient and referred tests are excluded.

No. of Tests Ordered By EMR (Proportion of Tests Accounted for by EMR Orders)						
Hospital	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
A	0 (0.00%)	57125 (9.87%)	451671 (79.09%)	496686 (82.42%)	517068 (82.84%)	479558 (82.22%)
B	0 (0.00%)	5944 (10.43%)	36845 (66.13%)	40530 (68.35%)	41542 (67.90%)	39846 (66.08%)
C	0 (0.00%)	12485 (7.45%)	106403 (64.28%)	112378 (66.99%)	124622 (67.13%)	137721 (68.45%)
D	0 (0.00%)	77658 (42.93%)	154825 (84.92%)	160650 (84.81%)	163223 (84.89%)	148103 (83.41%)
E	128296 (18.23%)	584289 (80.64%)	621389 (80.44%)	676150 (81.84%)	682360 (81.97%)	607332 (80.68%)
F	0 (0.00%)	374120 (66.57%)	453644 (82.13%)	484770 (81.54%)	520854 (82.18%)	522876 (80.96%)
Overall	128296 (5.84%)	1111621 (48.96%)	1824777 (79.35%)	1971164 (80.79%)	2049669 (81.03%)	1935436 (79.95%)

ETHICS APPROVAL

Ethics approval was granted by the South Eastern Sydney Local Health District Human Research Ethics Committee (HREC; Project No. 11/146).

DATA SOURCES

Table 4 shows summary information for the source, contents and size of each dataset that was used in this project. The LIS provided laboratory test order information at a test level for the six study hospitals for a period of six years (the 2008-2013 calendar years). The PASs for three administratively independent groups of hospitals (A+B+E, C alone and D+F) provided all the patient admission and discharge records for the six study hospitals for a period of six years (the 2008-2013 calendar years). The Emergency Department information systems for three administratively independent groups of hospitals (A+E, C alone and D+F; Hospital B did not operate an ED) provided all ED presentation records for five study hospitals for a period of six years (the 2008-2013 calendar years). An EMR data extraction using Cerner Command Language (CCL), via the Cerner Discern Explorer environment interface, provided information for all the pathology test and radiology procedures conducted at the six study hospitals, and whether they were ordered as part of a Careset (a designated set of tests that were available within the Cerner EMR system to be ordered by clinicians), for the month of September 2013.

A data extraction from the Cerner FirstNet recorded all patient location changes within the ED (especially movements between the waiting room, non-acute treatment areas and acute treatment and resuscitation

areas) for the five study EDs for the month of December 2013. A data extraction from the Medical Imaging department Radiology Information System (RIS) at Hospital A provided information for all the imaging procedures conducted in the Hospital A's ED for the 2013 calendar year.

Table 4. A summary of the different datasets and, for each dataset, the source, the type of data contained, the organisations described, the period of time described and the number of rows (prior to data cleaning).

Dataset name	Dataset source	Data content	Organisation Described	Period covered	No. of rows
LIS	Pathology Service LIS	Laboratory test orders	Hospitals + EDs: ABCDEF	2008-2013	25,550,332
PAS	3 x PAS extractions	Hospital Admission / Discharge	Hospitals: ABCDEF	2008-2013	1,194,127
ED	3 x ED extractions	ED Presentation	EDs: ACDEF	2008-2013	1,402,691
Caresets	Cerner Discern Explorer interface to EMR	Pathology / Imaging Orders & Caresets	Hospitals + EDs: ABCDEF	Sep 2013	289,417
Locations	Cerner FirstNet	Patient movements within EDs	EDs: ACDEF	Dec 2013	97,548
Imaging	Hospital A Imaging Dept.	Radiology / Imaging	ED: A	Jan-Dec 2013	19,331

DATA EXTRACTION

The initial LIS data extraction generated a dataset containing information relating to all pathology tests conducted on specimens received by the pathology service departments in the period January 2008 and December 2013. The LIS dataset contained 25,550,332 records. No duplicate entries (where the values in every field were identical) were found in the dataset. Of these records, 311,089 were removed because they related to laboratory workflow rather than identifying an actual test order. This left 25,239,251 pathology test records associated with 616,013 patient records (who may have had multiple admissions in hospital or presentations at ED). This dataset formed the basis for the subsequent analysis of test volume and TATs. Another adjustment was made to these data to account for a small proportion of tests where, due to errors in manual data entry into the LIS, the TAT was recorded with a value less than or equal to zero minutes (for Total Laboratory TAT, 25,117 such records were found). These records were flagged and did not contribute to analyses of TATs, but were included in other analyses.

In order to assess the volume of test ordering per patient encounter (from patient admission to the hospital until their discharge) it was necessary to extract patient encounter data from the PAS and ED information system of the hospitals. These patient encounter data included all inpatient admissions and ED presentations that began between 1 January 2008 and 31 December 2013. The final linkage occurred between records for 1,194,127 patient admissions (extracted from the PAS), records for 1,402,691 ED presentations (extracted from the ED information system) and the records for 25,239,251 pathology test orders (extracted from the LIS).

DATA STANDARDISATION AND QUALITY VERIFICATION

This project utilised raw data extracted from a variety of different sources: the pathology service LIS, the PAS at three administratively independent groups of hospitals, the ED information system at three administratively independent groups of hospitals, Cerner FirstNet, the Imaging department at one hospital and Cerner Discern Explorer interface to the EMR. A number of data standardisation and quality verification steps were undertaken to optimise the datasets that would be used for linkage and analyses.

These standardisation and verification steps included:

- Removing duplicate rows (where all fields were identical).
- Removing and accounting for LIS records that relate to laboratory workflow rather than actual tests.
- Standardising LIS test set codes between different sites of the pathology service, such as adding leading zeroes to test set codes when they were missing.
- Standardising LIS test set names between different sites of the pathology service, such as different nomenclature for equivalent test sets such as 'EUC' and 'UEC' or different Troponin assays.
- Standardising Major Diagnostic Block (MDB), URG, Mode of separation and other codes coming from ED information systems that feature slight variations in nomenclature.
- Removing and accounting for test orders for closely related test sets, such as Automated Differential and Full Blood Count (FBC) that appear as two separate tests in the LIS although the latter is included as part of the former.
- Removing specimen collection time stamps with low reliability, such as when the time stamp is the same or after the CSR registration time.
- Remove TATs with negative values or unreliable collection timestamps, due to errors in manual data entry into the LIS.

DATA LINKAGE

All data integrity and validity checks, and linkage, were performed in IBM SPSS Statistics 22.0.0. The datasets extracted from the PAS and ED information system were comma-separated values (CSV) and Microsoft Excel (XLSX) format; the in-built SPSS data opening functions were used to import the data.

PATHOLOGY UTILISATION DATASET

This dataset covered six study hospitals for the six year study period between 2008 and 2013. The patient admission dataset from the PAS and the ED presentation dataset from the ED information system were merged with the laboratory test order dataset from the LIS and the entire merged dataset was sorted by patient, inpatient admission or ED presentation dates and times and specimen collection dates and times. Test orders where the specimen was collected after the patient admission, or presentation at ED, and before

the patient discharge could be confidently attributed to those patient encounters. Data linkage between the three datasets allowed a single test order to be linked with either the PAS or ED information system dataset, or both datasets simultaneously. The SPSS 'LAG' function was used to compare the patient, inpatient admission or ED presentation dates/times and specimen collection dates/times of the sorted merged datasets and to associate, where valid and appropriate data were found, inpatient admission or ED presentation, discharge and demographic information with the relevant test order data. In cases where specimen collection for a test order occurred either before patient admission or ED presentation, after patient discharge, or where no patient encounter data could be found, no linkage was performed. Therefore, these test orders were excluded from all analyses where linked data were necessary (e.g. analyses of DRG or MDB/URG casemix). Once the linkable patient presentation and admission data from the ED information system and PAS datasets were merged, the merged dataset was cleaned to remove orphan patient admission or ED presentation information (presentations and admissions for which no associated pathology tests were found).

ED LOS DATASET

This dataset covered the ED at Hospital A only for the 2013 calendar year. The data linkage for this dataset followed the same logic as for 'Pathology utilisation dataset' but, rather than all linkage centring on the LIS dataset, the ED dataset was made central to all linkage. Initially, all PAS data for inpatient admissions that were registered within ±24 hours of ED discharge for the same patient were linked with that ED admission. Independently, all the Imaging procedure order data were appended to the pathology test order dataset from the LIS (so, imaging procedures and pathology tests were represented in the same way in the dataset). The PAS/ED linked data and the laboratory/imaging order merged data were appended and, as with the 'Pathology utilisation dataset', the entire merged dataset was sorted by patient, inpatient admission or ED presentation dates and times and specimen collection/imaging procedure start dates and times. Test orders where the specimen was collected (or the imaging procedure was started) after the patient admission, or presentation at ED, and before the patient discharge could be confidently attributed to those patient encounters. Data linkage between the four datasets allowed a single ED presentation to be linked with the PAS and/or LIS and/or Imaging datasets, or any combination thereof. The SPSS 'LAG' function was used to compare the patient, inpatient admission or ED presentation dates/times and specimen collection/imaging procedure start dates/times and create a link where the test and imaging start time fell within an inpatient admission or ED presentation. Once the linkable test and imaging order data and admission data from the ED information system and PAS datasets were merged, the merged dataset was cleaned to remove orphan test and imaging order data – that is, laboratory tests and imaging procedures that were not ordered during an ED presentation or an inpatient admission occurring within 24 hours from ED discharge.

ED PATIENT MOVEMENTS DATASET

This dataset covered the EDs at five study hospitals (Hospital B did not operate an ED) for the month of December 2013. The data linkage for this dataset followed the same logic as for 'Pathology utilisation dataset'. The patient time-in location and time-out-of location data from the Locations dataset from Cerner FirstNet were merged with the already-linked 'Pathology utilisation dataset' (described above) and the entire merged dataset was sorted by patient, time-into location and specimen collection dates and times. Test orders where the specimen was collected after the time-into location time, and before the time-out-of location time could be confidently attributed to those patient encounters. The SPSS 'LAG' function was used to compare the patient, time-into and time-out of location dates/times and specimen collection dates/times of the sorted merged datasets and to associate, where valid and appropriate data were found, patient location time-in location and time-out-of location data with the relevant test order data. In cases where specimen collection for a test order occurred either before time-in location, or after time-out-of location, or where no time-in or time-out-of location data could be found, no linkage was performed. Therefore, these test orders were excluded from all analyses where linked patient movement data were required. Once the linkable patient movement data from the Locations dataset were merged, the merged dataset was cleaned to remove orphan time-in and time-out-of location information (patient movement records for which no associated pathology tests were found).

CARESET UTILISATION DATASET

This dataset covered the six study hospitals for the month of September 2013. The data linkage for this dataset followed the same logic as for 'Pathology utilisation dataset'. The patient admission dataset from the PAS and the ED presentation dataset from the ED information system were merged with Caresets dataset from Cerner Discern Explorer interface to the EMR and the entire merged dataset was sorted by patient, inpatient admission or ED presentation dates and times and pathology test order or imaging procedure order dates and times. Test/procedure orders that were created after the patient admission, or presentation at ED, and before the patient discharge could be confidently attributed to those patient encounters. Data linkage between the three datasets allowed a single test or procedure order to be linked with either the PAS or ED dataset, or both datasets simultaneously. The SPSS 'LAG' function was used to compare the patient, inpatient admission or ED presentation dates/times and pathology test order or imaging procedure order dates/times of the sorted merged datasets and to associate, where valid and appropriate data were found, inpatient admission or ED presentation, discharge and demographic information with the relevant test or procedure order data. In cases where a test or procedure order occurred either before patient admission or ED presentation, after patient discharge, or where no patient encounter data could be found, no linkage was performed. Therefore, these test or procedure orders were excluded from all Careset utilisation analyses. Once the linkable patient presentation and admission data from the ED information system and PAS datasets were merged, the merged dataset was cleaned to remove orphan patient admission or ED

presentation information (presentations and admissions for which no associated pathology test or imaging procedure orders were found).

DATA ANALYSIS AND STATISTICAL METHODS

Data analyses were conducted using IBM SPSS Statistics 22.0.0, SAS Institute Statistical Analysis System (SAS) versions 9.3 and 9.4 and Microsoft Excel 2010.

STATISTICAL METHODS FOR POISSON MODELLING

To assess test volume for each patient at different hospitals over six years, Poisson modelling was adopted. The average number of tests per patient day for inpatients with its 95% CIs was estimated from the following models:

- with adjustment for hospital and year.
- with adjustment for hospital, year, DRG, age and gender.

STATISTICAL METHODS FOR ED LOS ANALYSES

We used Generalised Estimating Equation (GEE) modelling to take into account the correlation between multiple ED presentations by the same patients and used a log-link function and gamma distribution to fit skewed ED LOS data. All the patient demographics and presentation characteristics were adjusted in the models and integration between variables of interest, i.e. testing characteristics, and the mode of separation were considered.

OUTCOME MEASURES

TEST UTILISATION

The project used the following Test Utilisation outcome measures:

- Mean number of tests per patient per day per DRG.
- Mean number of tests per inpatient admission per DRG.
- Mean number of tests per ED presentation per MDB.
- Mean, median and variation, in test volume per patient day per clinician per DRG.

APPROPRIATENESS

- Graph plots showing the rate of increase of the number of repeat tests of the same type and for the same patient, as a proportion of all tests of that type, as time elapsed from the previous test (rates reported at both an Overall level and for specific DRGs)
- The selection of certain tests that should only be used selectively, or there is evidence that they are 'over-utilised', and compare the MDBs with which they are associated at each study ED.
- The selection of certain ED presentation MDBs (as broad proxy categories for the types of patient presentations at EDs) to compare the types of tests being ordered in the first test order episode at different EDs.

- The selection of 'Chest Pain' DRG (F74Z) to compare the test volume for the Top-10 tests between: a) inpatients; b) ED patients who were eventually admitted and c) ED patients whose treatment was completed within the ED, across four study Hospitals and EDs.
- Comparison of Careset utilisation at the six study hospitals, which Caresets were most frequently used, what tests were most frequently ordered as part of Caresets and which DRGs and MDBs were associated with the greatest Careset utilisation.

PATIENT OUTCOMES

- The selection of 'Chest Pain' DRG (F74Z) to compare the total TATs (from when the specimen was collected to when a result was made available) for the Top-10 tests between inpatients with matched ED patients who were eventually admitted and equivalent ED patients (based on the MDB classification) whose treatment was completed within the ED, at four study EDs.
- The utilisation of multilevel modelling – controlling for confounding variables including hospital, year, patient age and sex – for the presentation, to assess the impact of pathology testing and imaging procedure utilisation on patients' length of stay in the EDs.

COST-CONTROL

- An examination of the relationship between the mean number of pathology tests ordered, for ED presentations belonging to different URG categories, and the dollar amount reimbursement received by the ED.
- An examination of the relationship between the mean Length of Stay in the ED, for ED presentations belonging to different URG categories, and the dollar amount reimbursement received by the ED.

SECTION VI: ASSESSING OVERALL TEST UTILISATION VOLUME

INTRODUCTION

It has been estimated that pathology laboratories typically experience workload increases of between five to ten percent per year.[8] Test order volumes can be affected by a variety of factors. Valenstein's 1996 study on managing physician use of laboratory tests identified type of hospital, seniority of medical practitioners and the number of clinicians who are responsible for a patient's care as key variables that may impact on test order volumes.[54]

METHODS

The analysis of test volume for the Top-10 DRGs with the highest pathology utilisation were generated by aggregating the 'Pathology utilisation dataset' into DRG groups and calculating the number of pathology tests, the number of patient admissions and the mean hospital length of stay in each group, collapsing the data between the six study hospitals. The DRGs were ranked according to the raw frequency of pathology tests in each one (ignoring the number of patient admissions or the mean length of stay). The study period covered all six calendar years between 2008-2013. The same process was repeated for the analysis of test volume for the Top-10 MDBs with the highest pathology utilisation in the ED. There were only five study EDs (Hospital B did not operate an ED). The study period for ED analyses was limited by when MDB coding was introduced in each ED (July 2009 to December 2013 in EDs A, D, E and F; July 2008 to December 2013 in ED C).

STATISTICAL METHODS

To assess test volume for each patient at different hospitals over six years, Poisson modelling was adopted. The average number of tests per patient day for inpatients with its 95% CIs was estimated from the following models:

- with adjustment for hospital and year (crude rates)
- with adjustment for hospital, year, DRG, age and gender (adjusted for casemix and patient characteristics).

RESULTS

Table 5 lists the Top-10 DRGs with the highest pathology test utilisation. Dividing the total test volume by the number of patient admissions for each DRG allows the calculation of a mean test rate per patient admission. The mean length of stay, in hours, is also provided.

'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' (A06B) was the DRG with the largest total test volume when considering all six years of data. However, when analysing the test volume on a yearly basis, the annual test volume during the final three years of the analysis (2011-2013) was lower for this DRG than for 'Rehabilitation W/ Cat CC' (Z60A). While considering the mean rate of pathology tests per patient admission, 'Tracheostomy W/ Vent >95 hours W/ Cat CC' (A06A) had the highest rate of pathology test

utilisation. However, it should be noted that this DRG was also characterised by the longest mean length of stay.

On the other end of the scale, 'Haemodialysis' (L61Z), 'Chest Pain' (F74Z) and 'Chronic Obstructive Airways Disease W/O Cat CC' (E65B) were characterised by the lowest rates of pathology testing per admission (out of the Top-10 list) and the shortest mean length of stays. Their inclusion in the Top-10 list is due to the study hospitals having much higher rates of patient admissions registered with these DRGs.

Comparisons across time show that the overall number of tests for the Top-10 DRGs increased at a faster rate than the number of admissions, resulting in an average of 6.6 additional tests per admission in 2012 (where the number of tests per admission peaked) compared to 2008; the number of tests per admission decreased in 2013. Our investigation of individual DRGs indicates that this overall pattern is not universal. 'Rehabilitation W/ Cat CC' (Z60A), 'Rehabilitation W/O Cat CC' (Z60B), 'Chest Pain' (F74Z) and 'Respiratory Infections/Inflammations W/ Cat CC' (E62A), all had lower mean rates of tests per admission in 2012/2013 compared to 2008/2009 because the increase in the number of tests was accompanied by an even greater increase in the number of admissions. 'Chronic Obstructive Airways Disease W/O Cat CC' (E65B) is a noteworthy DRG because it actually had both a decreasing number of tests and a decreasing number of admissions over the study period.

The overall mean length of stay for the Top-10 DRGs was longer in 2012/2013 than in 2008/2009 but this effect was driven by the two Tracheostomy DRGs (A06A and A06B). The remaining eight DRGs all had shorter mean lengths of stay at the end of the study period compared to the beginning. See Appendix A for a more detailed version of Table 5 that includes a hospital by year comparison.

Table 5. The Top-10 DRGs accounting for the highest pathology test utilisation. Collapsed across the six study hospitals. Study period January 2008 to December 2013.

		Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours					
DRG		**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
A06B	Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC	210.10 (73534/350) 731	198.65 (73899/372) 725	200.56 (74609/372) 777	203.70 (77815/382) 785	215.82 (89995/417) 747	199.99 (85195/426) 769
Z60A	Rehabilitation W/ Cat CC	107.39 (54769/510) 1320	108.13 (68228/631) 1348	111.80 (71328/638) 1432	121.44 (85734/706) 1507	101.99 (93019/912) 1166	85.28 (88348/1036) 943
A06A	Tracheostomy W/ Ventilation >95 hours W/ Cat CC	411.47 (52668/128) 1575	379.51 (48577/128) 1712	353.27 (45925/130) 1674	337.89 (44263/131) 1648	419.64 (35669/85) 2105	380.12 (28129/74) 1733
L61Z	Haemodialysis	4.70 (43767/9310) 7	4.61 (34259/7429) 7	4.72 (34256/7260) 7	4.78 (32785/6864) 7	4.94 (30477/6171) 7	4.91 (30934/6295) 7
G02A	Major Small and Large Bowel Procs W/ Cat CC	90.34 (22404/248) 535	105.85 (27944/264) 617	98.39 (30009/305) 591	117.08 (35592/304) 514	102.33 (37146/363) 493	102.16 (38412/376) 508
F74Z	Chest Pain	8.82 (25861/2933) 28	9.41 (24711/2627) 33	9.41 (27785/2954) 30	8.67 (29017/3346) 26	8.20 (30122/3673) 22	7.83 (26866/3430) 21
E62A	Respiratory Infections/Inflammations W/ Cat CC	42.84 (23262/543) 272	40.34 (22226/551) 251	40.66 (22040/542) 277	42.57 (27925/656) 283	39.30 (34937/889) 248	33.54 (27872/831) 233
T60A	Septicaemia W/ Cat CC	58.45 (19170/328) 296	55.45 (21515/388) 302	56.97 (23302/409) 285	62.80 (24052/383) 333	61.16 (30151/493) 320	49.28 (33655/683) 282
Z60B	Rehabilitation W/O Cat CC	49.12 (19942/406) 928	49.85 (21684/435) 996	56.89 (23554/414) 1055	55.92 (22761/407) 1230	45.30 (26907/594) 875	36.77 (29124/792) 629
E65B	Chronic Obstructive Airways Disease W/O Cat CC	17.18 (21614/1258) 132	17.43 (21827/1252) 129	16.59 (20585/1241) 118	16.64 (21434/1288) 119	16.71 (20303/1215) 111	13.14 (14544/1107) 101
Overall (Top-10 DRGs)		22.29 (356991/16014) 137	25.92 (364870/14077) 177	26.18 (373393/14265) 182	27.74 (401378/14467) 196	28.94 (428726/14812) 195	26.78 (403079/15050) 182

Table 6 lists the Top-10 MDBs with the highest pathology test utilisation. Dividing the total test volume by the number of ED presentations for each MDB allows the calculation of a mean test rate per ED presentation. The mean length of stay, in minutes, is also provided. It is important to note that the data for 2008 only include the six-month period Jul-Dec at a single ED (Hospital C); this is also the case for the first half of 2009. From the second half of 2009 onwards all five study EDs are represented.

'Circulatory system illness' (3A) had the largest total test volume when considering all six years in the data. However, in 2013 'Digestive system illness' (3C) actually had both higher test volume and a greater number of ED presentations. Compared to the DRGs, there is much less variability between MDBs for all four measures reported.

Table 6 shows that ED presentations registered with 'Hepatobiliary system illness' (3Q) consistently had the highest mean rate of pathology tests per patient presentation, but were also associated with the longest stays in the ED.

On the other end of the scale, 'Urological system illness patients' (3D) and 'Other presentation' (6) patients were characterised by the lowest rates of pathology testing per admission (out of the Top-10 list) and the shortest mean length of stays.

Unlike the situation with inpatient DRGs, when excluding the 2008 and 2009 data which do not represent all the hospitals, a longitudinal comparison across time shows that the overall number of tests for the Top-10 MDBs increased but was matched by the number of ED presentations. This is also true for all individual MDBs. Both 2012 and 2013 had lower overall mean test rates than the previous year (5.76 and 6.02, respectively, compared to 6.07 in 2011). This pattern in mean test rates per ED presentation is also reflected in the individual MDBs, which all showed either reduced (Circulatory, Neurological, Urological, Hepatobiliary and Psychiatric illnesses and Other presentations) or unchanged (Digestive, Respiratory and Blood/Immune System illnesses and System infection/parasites) mean test rates per ED presentation.

The overall mean length of stay for the Top-10 MDBs was 33 minutes shorter in 2012 compared to 2010 and 2011, and reduced by a further 50 minutes in 2013. 'Circulatory system illness' (3A), 'Neurological illness' (3E), 'Urological illness' (3D) and 'Hepatobiliary system illness' all had reductions of at least 90 minutes in mean length of stay between 2010 and 2013. Of the remaining MDBs, all except for 'Psychiatric illness' (4) had mean lengths of stay decrease by at least 60 minutes between 2010 and 2013.

Table 6. The Top-10 MDBs accounting for the highest pathology test utilisation. Collapsed across the five study EDs (A, C, D, E and F). Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

Mean No. of Tests Per ED Presentation (No. of Tests/No. of ED Presentations) Mean Length of Stay in minutes

MDB		2008	2009	2010	2011	2012	2013
3A	Circulatory system illness	6.62 (510/77) 292	6.47 (46837/7234) 412	6.50 (94524/14541) 448	6.39 (97386/15239) 449	6.24 (108161/17346) 419	5.97 (110746/18564) 358
3C	Digestive system illness	4.42 (3727/844) 378	5.68 (48376/8523) 440	5.85 (87457/14959) 454	5.89 (92351/15689) 464	5.83 (104534/17944) 422	5.67 (115249/20314) 379
3B	Respiratory system illness	3.85 (3102/806) 302	5.92 (33925/5728) 419	6.08 (56227/9250) 455	6.20 (59841/9645) 456	6.26 (65688/10487) 443	6.03 (63661/10549) 390
3E	Neurological illness	6.93 (1407/203) 376	6.03 (26422/4385) 475	5.92 (50263/8487) 506	5.95 (51552/8664) 511	5.77 (57483/9970) 461	5.48 (62639/11438) 400
3N	System infection/parasites	5.86 (3287/561) 334	5.95 (19722/3317) 389	6.01 (36634/6097) 422	5.98 (38645/6466) 409	6.24 (44392/7109) 385	6.08 (51544/8471) 356
3D	Urological illness	3.92 (682/174) 250	5.16 (16412/3180) 402	5.33 (31903/5982) 435	5.34 (31608/5923) 431	5.29 (33832/6400) 396	4.93 (33930/6880) 336
6	Other presentation	4.73 (838/177) 290	5.29 (9315/1761) 401	5.34 (12712/2379) 422	5.34 (12558/2352) 406	5.12 (16096/3144) 378	4.86 (20221/4160) 336
3J	Blood/immune system illness	5.86 (967/165) 271	6.66 (6995/1050) 383	6.94 (12797/1843) 460	6.80 (11735/1727) 451	6.93 (14488/2091) 402	6.41 (14758/2304) 381
3Q	Hepatobiliary system illness	6.23 (81/13) 339	7.98 (6330/793) 510	8.12 (12143/1495) 545	7.87 (12336/1568) 555	7.93 (13590/1713) 512	7.49 (15047/2010) 449
4	Psychiatric illness	5.00 (95/19) 369	6.19 (5443/880) 455	6.12 (10688/1747) 478	6.18 (11483/1857) 466	6.11 (14056/2299) 448	5.82 (16569/2847) 423
Overall (Top-10 MDBs)		4.84 (14696/3039) 329	5.96 (219777/36851) 426	6.07 (405348/66780) 457	6.07 (419495/69130) 457	6.02 (472320/78503) 424	5.76 (504364/87537) 374

TEST VOLUME – CRUDE RATES

Another method to compare the test utilisation volume between different hospitals, and between different study periods, is to take the number of tests ordered, the number of admissions, and the mean length of stay for each hospital for each year of the study and calculate the mean number of tests per patient day. The advantage of this method is that it takes into account the variation in duration of patient stay.

Figure 2 shows this calculation for the four general hospitals (the specialist hospitals B and C are excluded) over the six year study period. Hospital D had a higher mean rate of tests per patient day than the other three hospitals (a difference of around 0.5 tests per patient day for 2008 to 2012 and 0.25 tests per patient day in 2013). Secondly, Hospital F showed greater variation in mean test rates per patient day, ranging from 3.7 in 2009 to 4.2 mean tests per patient day in 2012. Hospitals A and E had very similar mean rates of tests per patient day. Lastly, all hospitals had lower mean test utilisation in 2013 than in 2012 and, as already noted, the reduction was most dramatic at Hospital D.

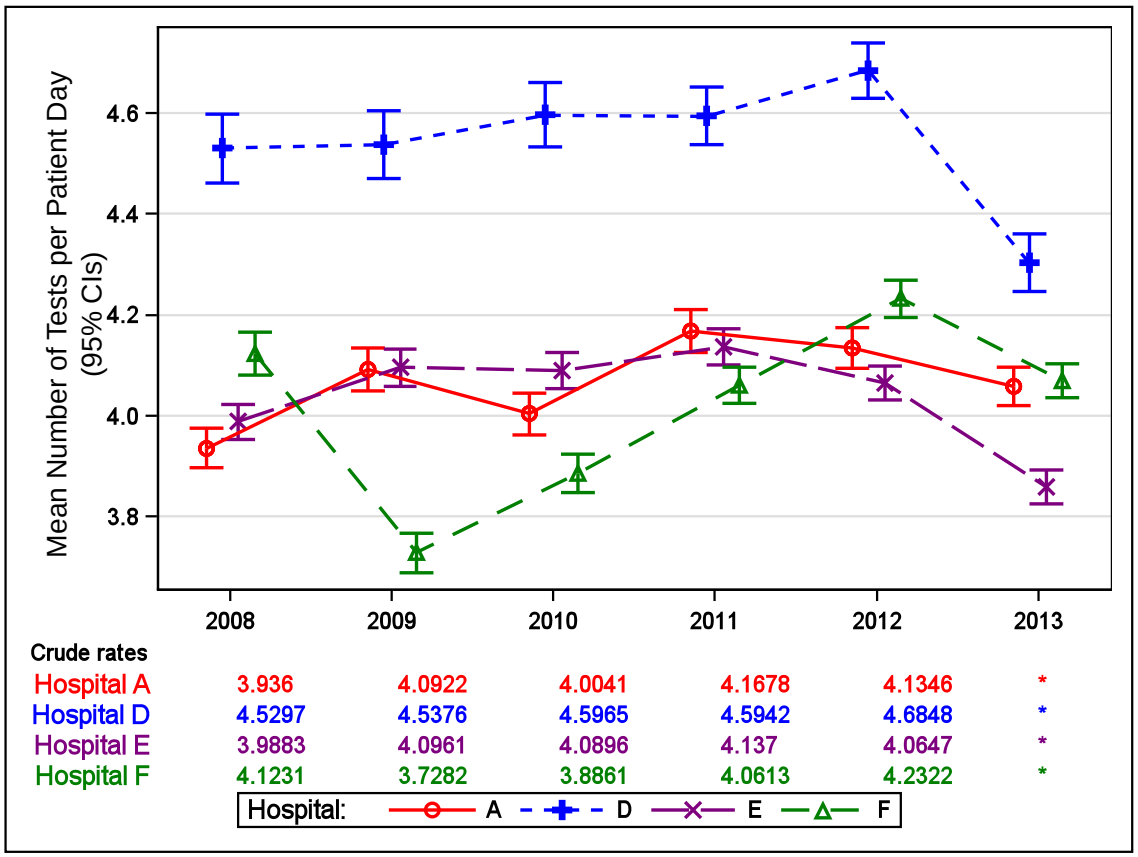

Figure 2. The 'crude' mean rate of pathology test volume per patient day at the four general hospitals A, D, E and F (the specialist hospitals B and C are excluded) over the six-year study period (January 2008 to December 2013).

The biggest limitation of this method is that, while it does take into account the patients' length of stay in the hospital, it does not take into account any other casemix variables (such as DRGs), and as shown in Table 5, the pathology testing profile can differ considerably between DRGs.

TEST VOLUME – ADJUSTED FOR CASEMIX AND PATIENT CHARACTERISTICS

For precisely the reasons described above, it is valuable for comparisons between hospitals, or across time, to take into account differences or changes in casemix and patient characteristics. It is possible for the mean test rate per patient day calculation to also take into account casemix and patient characteristics.

Figure 3 presents the same data as Figure 2, namely the comparison of mean tests per patient day at four different hospitals across the six year study period, but uses a Poisson model that applies an adjustment for Hospital, year, DRG category, patient age in years and patient gender.

When comparing Figure 3 to Figure 2, it is noticeable that the 'fitted' mean rate of tests per patient day was lower than the 'crude' rate (ranging from 3.0 to 3.9 tests per patient day, rather than 3.9 to 4.7 tests per patient day in Figure 2). Secondly, when controlling for casemix and patient characteristics, Hospital D was no longer the hospital with the highest mean rate of test orders per patient day. While Figure 2 showed that Hospitals A and E had very similar 'crude' mean tests per patient day rates, controlling for casemix and patient characteristics shows that Hospital E had a higher mean rate of test utilisation, that exceeded Hospital A by between 0.4 and 0.8 tests per patient day.

The temporal characteristics of Figure 3 show that the 'fitted' mean test rate generally increased with time from 2008 and 2009 through to 2011 and 2012, while Figure 2 shows a 'crude' mean test rate that was generally unchanged. Both figures show that the mean test rate per patient day was lower in all hospitals in 2013 than it was in 2012.

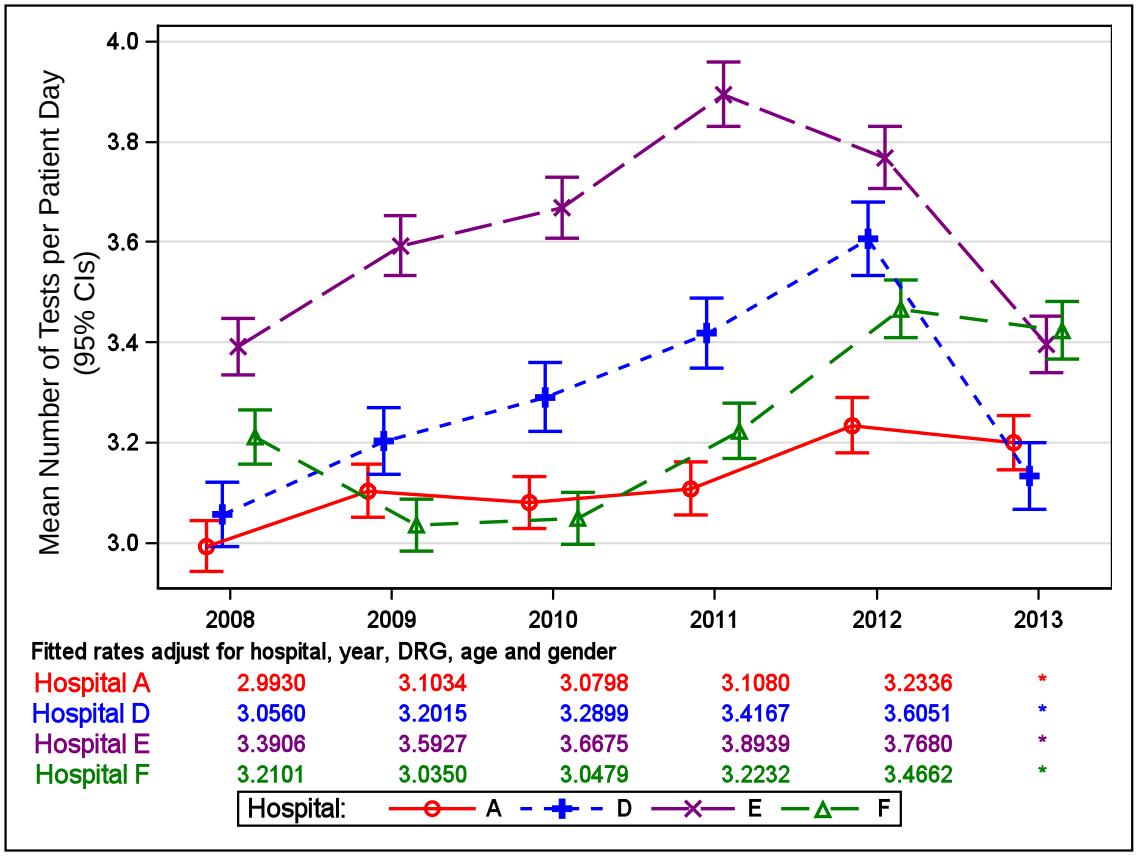

Figure 3. The 'fitted' mean rate of pathology test volume per patient day, adjusting for hospital, year, DRG, age and gender, at the four general hospitals A, D, E and F (the specialist hospitals B and C are excluded) over the six-year study period (January 2008 to December 2013).

TEST VOLUME – HOSPITAL COMPARISONS FOR SPECIFIC DRGS

Two of the Top-10 DRGs associated with the highest pathology test utilisation (as seen in Table 5) were chosen. For each of these chosen DRGs, a more detailed analysis was conducted of the test utilisation, including the degree of variation in test ordering practices at each hospital in each year of the study period (in addition to comparisons between hospitals and between years).

Box-plots were used to compare the mean and median rates of tests per patient days (the symbol in the box, and the horizontal stroke in the box, respectively) between hospitals and across years of the study period. The shaded boxes represent the IQR (the variation between the 25th and 75th percentile patient admissions) and the whiskers represent a further 1.5x of the IQR. Lastly, individual outlier patient admissions are represented individually with the appropriate symbol.

Figure 4 shows the mean and median rates of pathology tests per patient day, for patients admitted with the 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' DRG (A06B), which is characterised by very long mean length of stay, and relatively few patient admissions. It shows that the mean and median rates of pathology tests per patient day, for patients admitted with for 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC', did not vary much between hospitals or between years of the study. Hospital D is noteworthy in that it had very few patient admissions with this DRG but despite this did not show the largest variation;

Hospitals A and E frequently had a larger variation, shown by a wider IQR and whiskers. Hospital F frequently showed the least amount of variation as indicated by having the narrowest IQRs.

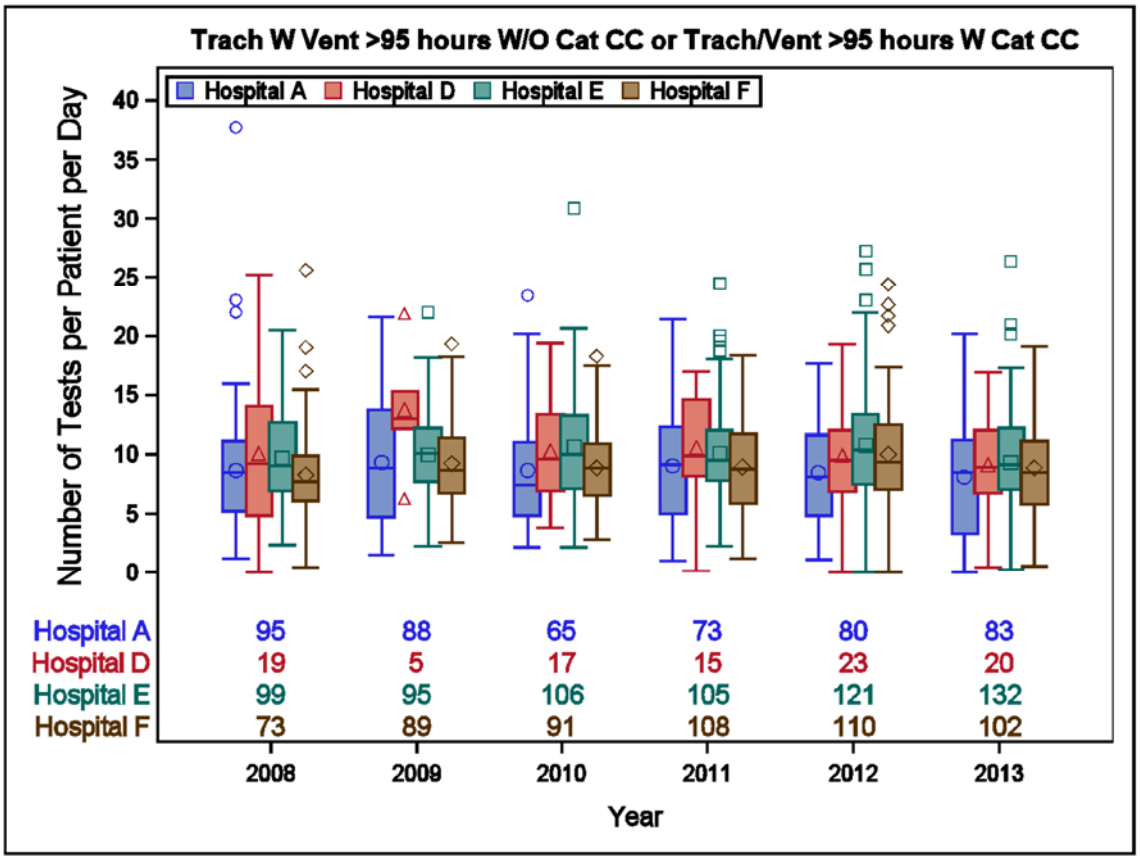

Figure 4. The 'crude' rate of pathology test volume per patient day, for the 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' DRG (A06B) at the four general hospitals A, D, E and F (the specialist hospitals B and C are excluded) over the six-year study period (January 2008 to December 2013). Numbers below plot show the number of patient admissions for this DRG at each hospital for each year in the study.

Figure 5 shows the mean and median rates of pathology tests per patient day, for patients admitted with the 'Chest Pain' DRG (F74Z), which is characterised by relatively short length of stay and a high number of patient admissions. The median rate of pathology tests per patient day was always highest at Hospital D and almost always the lowest at Hospitals A and E. However, the rate and variation did not change much between years of the study period.

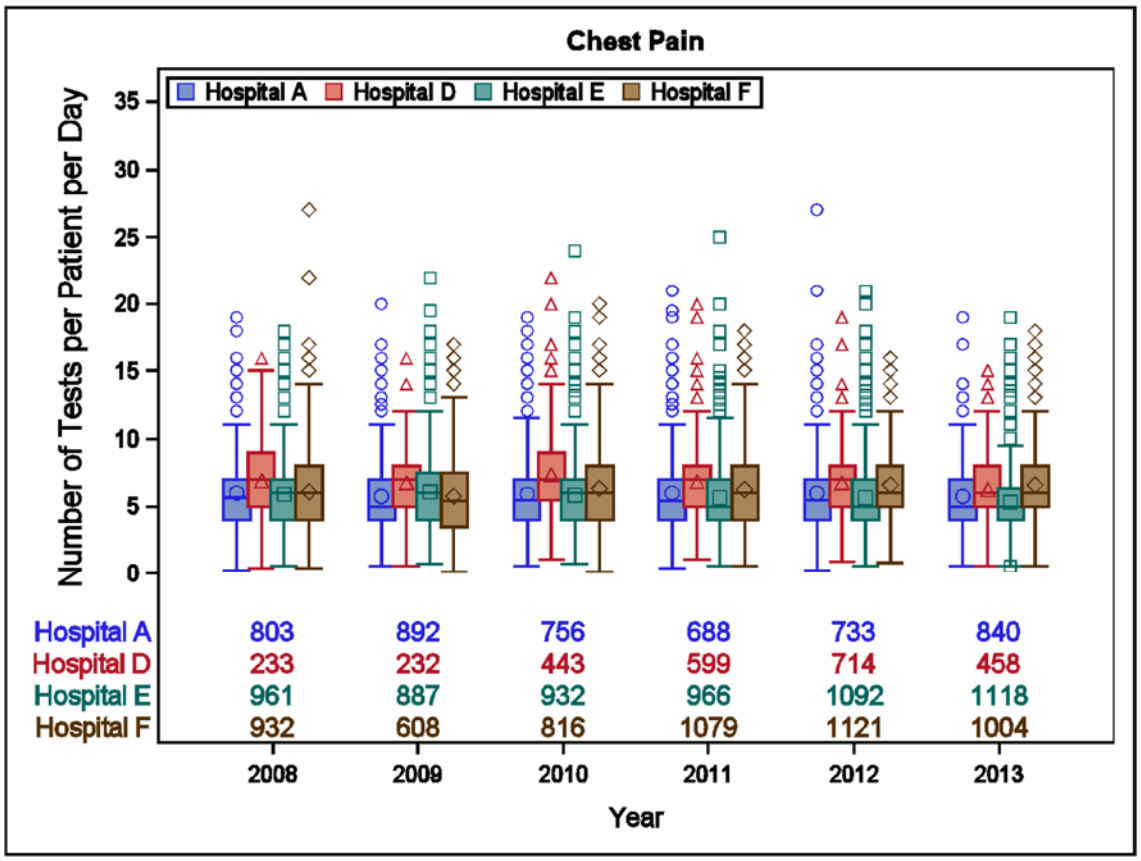

Figure 5. The 'crude' rate of pathology test volume per patient day, for the 'Chest Pain' DRG (F74Z) at the four general hospitals A, D, E and F (the specialist hospitals B and C are excluded) over the six-year study period (January 2008 to December 2013). Numbers below plot show the number of patient admissions for this DRG at each hospital for each year in the study.

SECTION VII: VARIATION IN PRACTICES BETWEEN CLINICIANS

INTRODUCTION

The ordering of laboratory tests can vary significantly across hospitals independent of patient acuity and the types of medical services available.[55] There are many reasons that may cause variations in clinical work practices. These can include pressure from the patient, peers or the hospital, clinical curiosity, insecurity or even habit.[56]

METHODS

The 'Chest Pain' DRG (F74Z) was chosen and all of the clinicians who ordered at least one pathology test for at least one patient registered with that DRG were selected. It was important that the results not be skewed by clinicians who were only briefly involved in caring for that patient. Therefore, an algorithm was devised where each patient admission was divided into smaller time slices according to the date and time of the patient admission, the date and time that each test was ordered and the date and time of the patient discharge. Each clinician was allocated the time slice of patient stay between the previous test ordered for that patient (by any clinician) and their own pathology test order. The time slices of each clinician for each DRG category were summed to get a measure of each clinician's involvement in the treatment of patients of this type. Clinicians only briefly involved in the caring for patients with a 'Chest Pain' DRG were defined as clinicians whose cumulative time slices across the entire study period was less than 24 hours. These clinicians were excluded from the analysis.

Once the clinician exclusion criteria were applied, the mean number of pathology tests per patient day for each clinician at each hospital were plotted in box plots. Each clinician contributed a single data point to the data for the 'Chest Pain' DRG but could potentially contribute data points to other DRGs if they were sufficiently involved in the treatment of patients in each of those DRG categories.

RESULTS

Figure 6 focuses on clinicians who ordered pathology tests for patients in the DRG of 'Chest Pain' (F74Z), and compares the variation in test volume utilisation between the four general hospitals over the entire six year study period. While the median clinician in Hospital D ordered fewer pathology tests per patient day than the median clinician at the other three hospitals, clinicians at Hospital D also had the greatest amount of variation in the mean number of tests ordered per patient day. Hospitals A and E had less variation, with the lowest variation found at Hospital F.

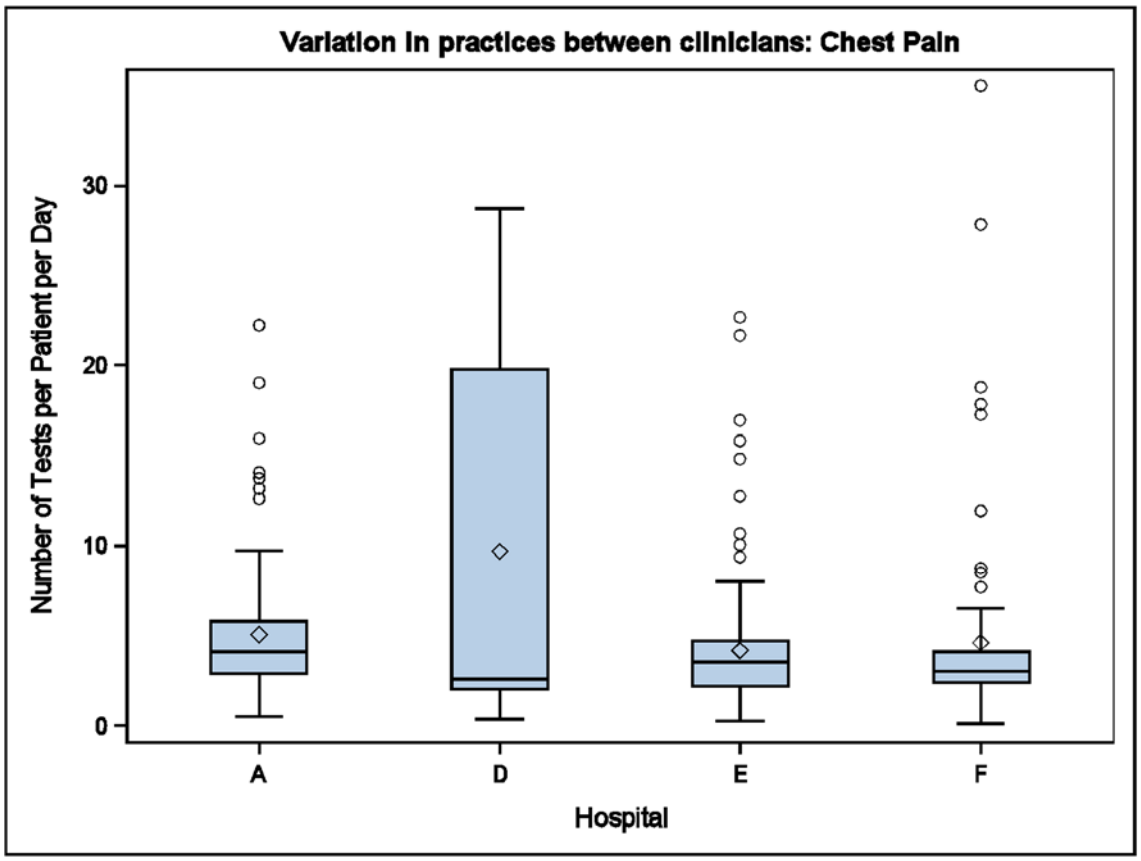

Figure 6. The variation between clinicians at each hospital, of the mean rate of pathology test volume ordered per patient day, for the 'Chest Pain' DRG (F74Z) at the four general hospitals A, D, E and F (the specialist hospitals B and C are excluded) over the six-year study period (January 2008 to December 2013). Each data point represents a single clinician in the hospital.

SECTION VIII: REPEAT TEST RATES

INTRODUCTION

Pathology laboratory test results are critical to the delivery of safe and quality patient care. The appropriateness of a test order needs to be assessed within the context of each patient's unique situation and condition. For instance, physicians in intensive care units are required to order some laboratory tests, such as blood gases, many times a day.[56] Research evidence has shown that there are times that a repeat test has been ordered without a clear clinical indication or need,[57] or within a time frame that is unlikely to yield additional information.[57,58]

METHODS

Repeat tests were identified as any test ordered for a patient where the same test had already been ordered for the same patient in the same hospital. The time delay between the current test and the previous test was calculated for each repeat test. Cumulative proportion plots were generated to show the contribution of repeat testing to total test volume (either Overall, or for a specific DRG).

During the ordering process the EMR displays a duplicate order alert if the same test is ordered for the same patient within 24 hours of the previous test. Where possible this is shown on each figure with a dotted vertical line. In addition, the minimum repeat testing intervals suggested by guidelines or other protocols in the literature are shown in each figure with a dashed vertical line. This analysis considered only the four general hospitals (A, D, E and F), while the specialist hospitals (B and C) were excluded. The study period was January 2008 to December 2013.

RESULTS

ELECTROLYTES, UREA, CREATININE

Figure 7 compares the cumulative proportion of repeat EUC tests, ordered within 48 hours of the same previous test for the same patient, to overall test volume. This analysis includes all DRGs, at the four general hospitals (A, D, E and F). Existing guidelines suggest that the minimum repeat test interval for EUC tests should be 12 hours[59] or 24 hours, with these time points indicated on FiguresFigure 7, Figure 8 andFigure 9.[60,61]

The repeat testing rates at the four hospitals follow similar trajectories up to 24 hours from the previous test. With a rate of approximately 25% of all EUC tests, Hospital D had the lowest proportion of repeat EUC tests within 24 hours; while the highest rate was observed at Hospital E (approximately 35%). The contribution of repeat testing on overall EUC test volume increased rapidly between 20 and 28 hours of the previous test at all hospitals. Repeat EUC tests within 48 hours of the previous test accounted for almost 50% of all EUC tests at Hospital D and between 60% and 65% at Hospitals A, E and F.

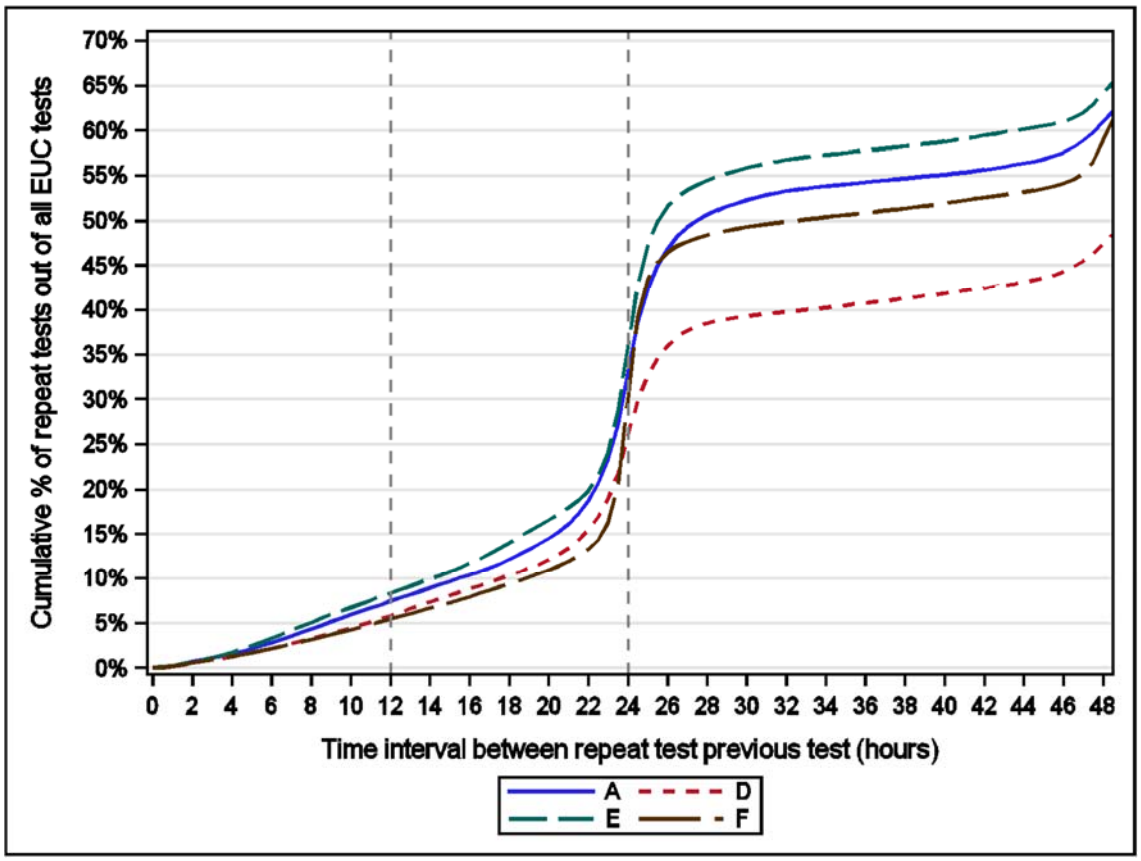

Figure 7. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat EUC tests that occur up to 48 hours from the previous EUC test for the same patient, for all DRGs.

Figure 8 compares the cumulative proportions of repeat EUC tests , ordered within 48 hours of the same previous test for the same patient, to overall test volume for the 'Tracheostomy W/ Ventilation W/ or W/O Cat CC' (A06B) DRG, at the four general hospitals (A, D, E and F.)

Repeat EUC tests within 24 hours at Hospitals D and E account for a greater proportion of EUC testing volume than at Hospital A and F. As was the case for all DRGs (Figure 7), there is a rapid increase in repeat EUC testing at all hospitals between 20 and 28 hours from the previous test. Between 85% and 90% of all EUC tests for Tracheostomy patients are accounted for by repeat tests within 48 hours of the previous test, a much greater proportion than when considering all DRGs (Figure 7).

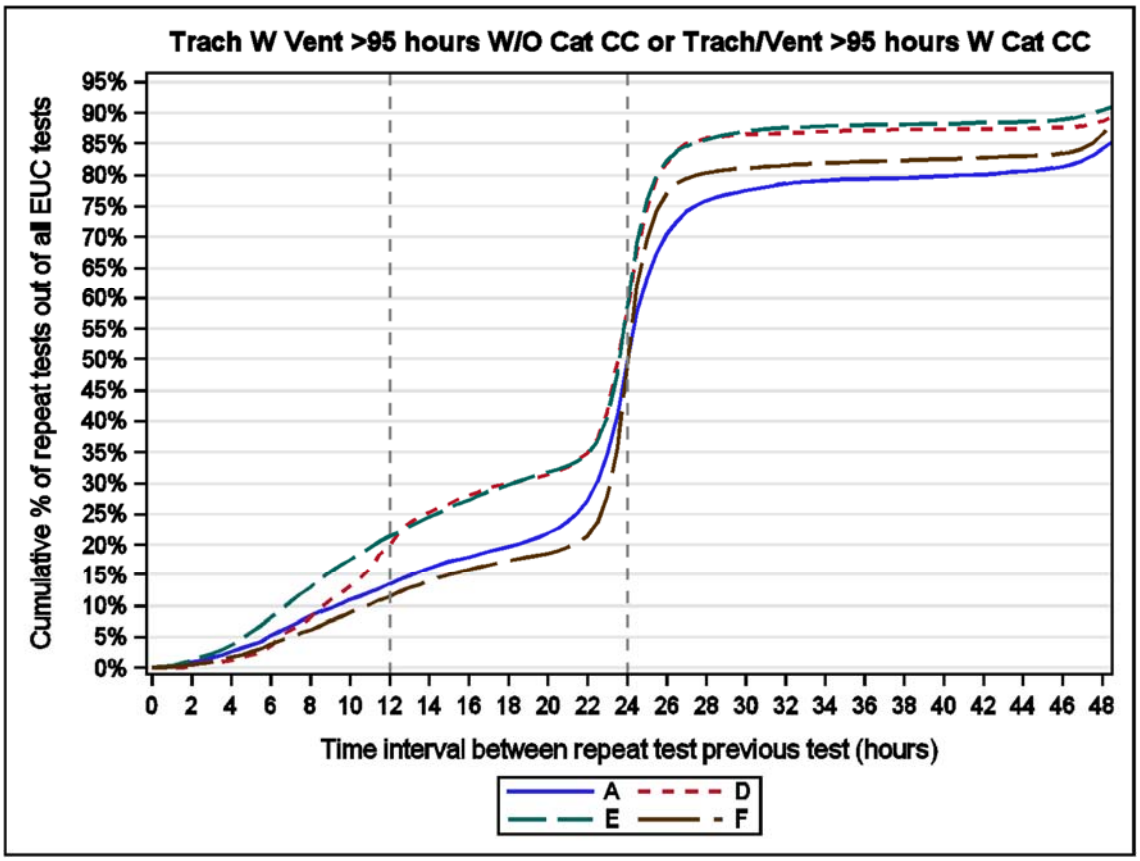

Figure 8. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat EUC tests that occur up to 48 hours from the previous EUC test for the same patient, for patients admitted with DRG of 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' (A06B) only.

Figure 9 compares the cumulative proportions of repeat EUC tests, ordered within 48 hours of the same previous test for the same patient, to overall test volume for the 'Chest Pain' DRG (F74Z), at the four general hospitals (A, D, E and F). Repeat EUC testing for Chest Pain patients has a very different profile to the repeat EUC testing rates for all DRGs (Figure 7) and the Tracheostomy DRG (Figure 8). Within ten hours of the previous EUC test, repeat EUC tests at Hospital A exceed 5% of total EUC volume, more than double the rate at Hospital D. The repeat EUC test rate within 24 hours exceeds 20% of total EUC volume at Hospital A, but was approximately 5% at Hospital D (Hospitals E and F have intermediate rates). Repeat EUC tests within 48 hours account for less than 10% of EUC tests at Hospital D, but the rate is approximately 25% at Hospital F and in excess of 30% at Hospitals A and E.

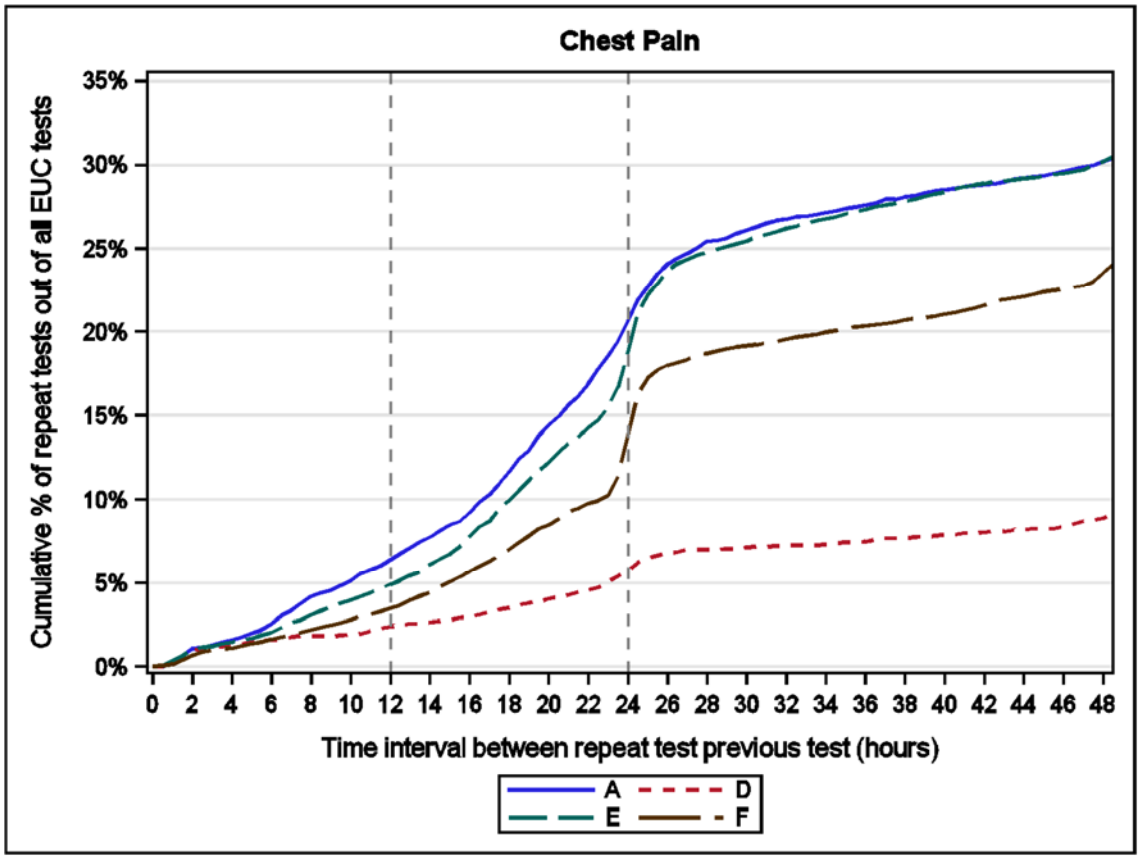

Figure 9. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat EUC tests that occur up to 48 hours from the previous EUC test for the same patient, for patients admitted with DRG of 'Chest Pain' (F74Z) only.

FULL BLOOD COUNT

Figure 10 compares the cumulative proportions of repeat FBC tests, ordered within 48 hours of the same previous test for the same patient, to overall test volume across all DRGs, at the four general hospitals (A, D, E and F). The guideline literature suggests that the minimum repeat test interval for FBC tests should be 12 hours,[59] as shown by the vertical dashed line in Figure 10,Figure 11 and Figure 12.

The repeat testing rate trajectories for FBC tests, for all DRGs (Figure 10), was similar to the trajectories for repeat EUC tests (Figure 7). The repeat testing rates at the four hospitals follow similar trajectories up to 24 hours from the previous test. With a rate of approximately 25% of all FBC tests, Hospital D had the lowest proportion of repeat FBC tests within 24 hours; with Hospital E having the highest rate (approximately 35%). The contribution of repeat testing on overall FBC test volume increased rapidly between 20 and 28 hours at all hospitals. Repeat FBC tests within 48 hours of the previous test accounted for approximately 45% of all FBC tests at Hospital D, and approximately 60% at Hospitals A, E and F.

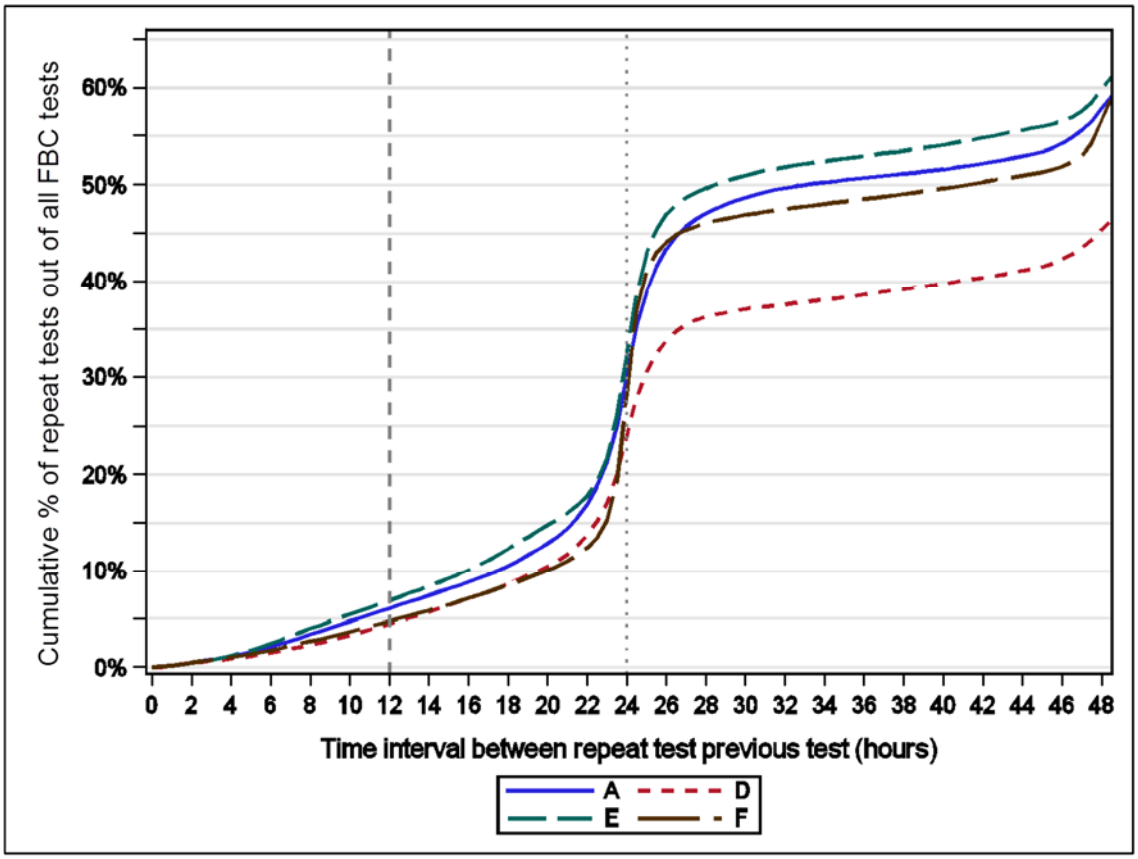

Figure 10. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat FBC tests that occur up to 48 hours from the previous FBC test for the same patient, for all DRGs.

Figure 11 compares the cumulative proportions of repeat FBC tests, ordered within 48 hours of the same previous test for the same patient, to overall test volume for the 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' (A06B) DRG, at the four general hospitals (A, D, E and F).

Repeat FBC testing for Tracheostomy patients (Figure 11) had a similar profile to repeat EUC testing for

Tracheostomy patients (Figure 8). In contrast to the repeat FBC testing for all DRGs (Figure 10), Hospital D does not show lower repeat testing rates. Instead, it has among the highest repeat testing rates.

Repeat FBC tests within 12 hours at Hospitals D and E account for more FBC testing volume (above 15%) than at Hospital A and F (approximately 10%). There is a rapid increase in repeat FBC testing at all hospitals around 24 hours from the previous test, mirroring the trend for all DRGs. In contrast to the overall repeat test rates shown in Figure 10, the repeat testing rates for FBC tests for Tracheostomy patients at Hospital D are the highest as a proportion of all FBC tests. Between 80% and 87% of the total FBC test volume for Tracheostomy patients are accounted for by repeat tests within 48 hours of the previous test. These proportions are similar to those for the repeat EUC test profile for Tracheostomy patients (Figure 8).

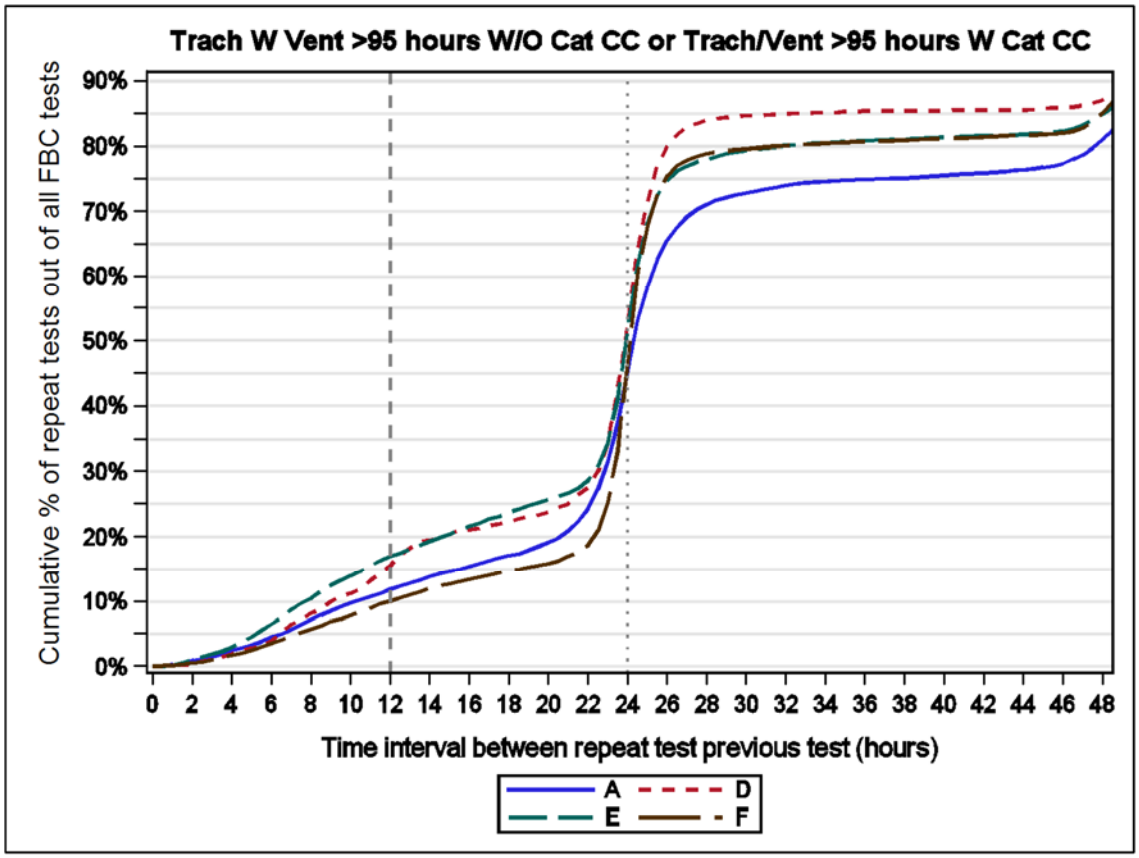

Figure 11. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat FBC tests that occur up to 48 hours from the previous FBC test for the same patient, for patients admitted with DRG of 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' (A06B) only.

Figure 12 compares the cumulative proportions of repeat tests, ordered within 48 hours of the same previous test for the same patient, to overall test volume for the 'Chest Pain' DRG (F74Z), at the four general hospitals (A, D, E and F).

Repeat FBC testing for Chest Pain patients has a similar profile to repeat EUC testing for Chest Pain patients (Figure 9) and thus, very different to the overall repeat FBC testing profile for all DRGs (Figure 10). Within fourteen hours of the previous FBC test, repeat EUC tests at Hospital A exceed 5% of total test volume, more than double the rate at Hospital D (less than 2%). The repeat FBC test rate within 24 hours was around 17% total test volume at Hospitals A and E, but was less than 5% at Hospital D (Hospital F had an intermediate rate). Repeat FBC tests within 48 hours account for approximately 7% of FBC tests at Hospital D, but the rate is approximately 20% at Hospital F and 27% at Hospitals A and E.

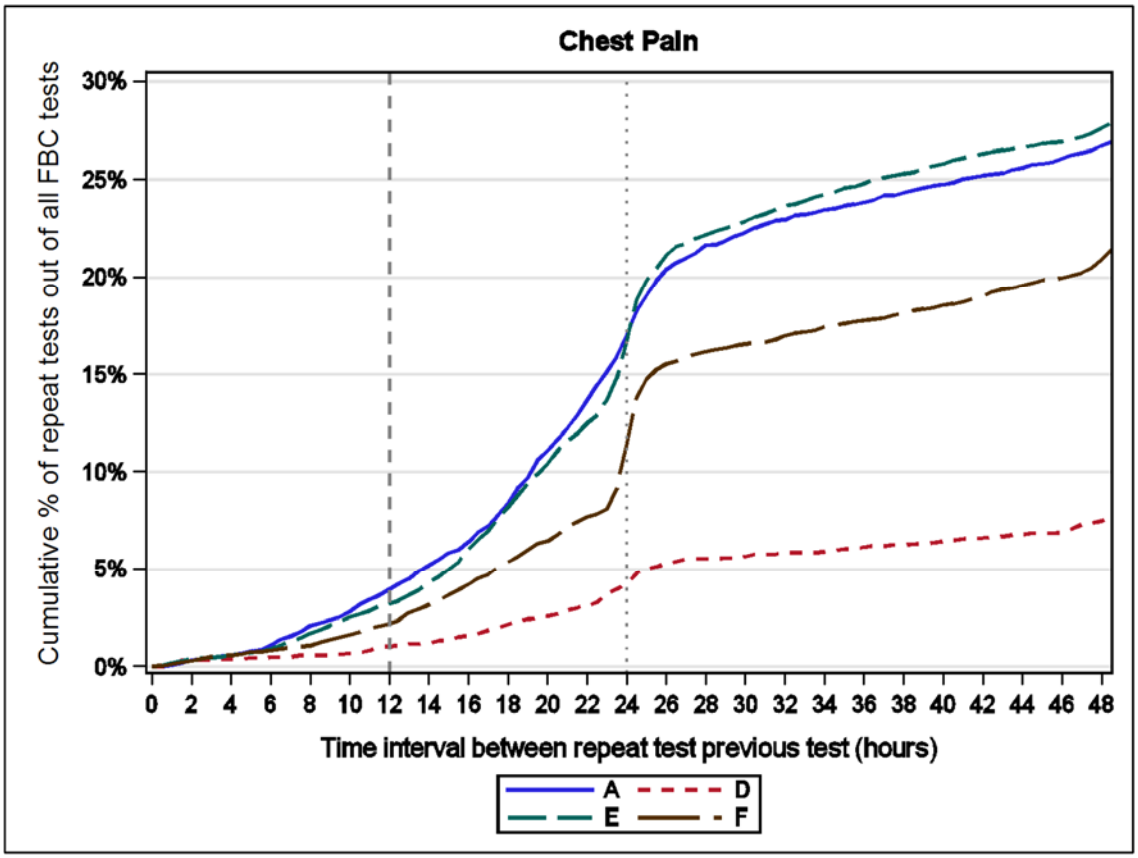

Figure 12. A comparison between the four general hospitals (A, D, E and F) of the cumulative proportion of repeat FBC tests that occur up to 48 hours from the previous FBC test for the same patient, for patients admitted with DRG of 'Chest Pain' (F74Z) only.

SECTION IX: TURN-AROUND TIMES

INTRODUCTION

Measurements of the quality and efficiency of pathology services generally focus on TATs – one of the most noticeable indicators of laboratory functioning.[62] This is because the timeliness of test results can impact on the time to make a diagnosis or begin treatment of a patient.[63] TAT can be used to measure one, or many, parts of the total testing cycle, including the ordering, collection, identification, transportation, preparation, analysis, reporting, interpretation and action. As a consequence, TAT can be influenced by a number of factors, from those related to bed numbers, location and hospital type, to those associated with the mode of specimen transportation, computerisation and clinical/laboratory work processes.[62,64]

METHODS

TAT was defined as the time between the specimen being collected and the time that the result was made available. A small number of tests did not have a collection time recorded in the LIS, or the collection time was deemed to be unreliable (1.4% of tests across all hospitals; ranging from 0.7% at Hospital F to 1.8% at Hospital A), so these tests were excluded from these analyses.

One DRG, 'Chest Pain' (F74Z) was chosen and compared to the matching populations in the ED: patients registered with the MDB 'Circulatory system illness' (3A) in Triage Categories 2 and 3 who were admitted as inpatients (who accounted for the vast majority of patients registered with the 'Chest Pain' DRG who came from the ED). Patients with the same MDB and Triage classifications, but whose treatment was completed within the ED, were also included for comparison.

The Top-10 tests with the highest pathology utilisation for patients registered with the DRG of 'Chest Pain' (F74Z) at one of the four general hospitals were selected (the specialist Hospitals B and C were excluded). All the TAT analyses focused on these ten tests. The DRGs for inpatients were available for all patients for the entire study period (January 2008 to December 2013) so the analysis period covered the entire study duration; MDBs for ED patients were only available at EDs A, D, E and F from July 2009 to December 2013, so the analysis period for these MDBs were restricted to those periods.

RESULTS

Table 7 shows TAT and test volume characteristics for the Top-10 tests with the highest utilisation for inpatients registered with the 'Chest Pain' DRG (F74Z). These characteristics were compared with equivalent patients within the ED, some of whom were eventually admitted as hospital inpatients, and others whose treatment was completed within the ED. Overall, pathology tests ordered for ED patients whose treatment was completed in the ED were processed the quickest, with a median TAT of 49 minutes; the TAT was 52 minutes for ED patients who were eventually admitted and 60 minutes for inpatients. Similarly the overall variability, as indicated by the IQR, was smallest for ED patients whose treatment was completed in the ED (IQR: 36-67 minutes); second smallest for ED patients who were eventually admitted (IQR: 37-77 minutes)

and greatest for inpatients (IQR: 42-95 minutes). The same pattern for both median TATs and variability was evident for almost all Top-10 tests considered in the analysis.

Troponin, EUC and FBC were the three most frequently ordered tests for inpatients and both categories of ED patients, accounting for between 47.7% to 56.2% of pathology testing for these patients. Test volume was greater for inpatients than ED patients, and greater for ED patients who were eventually admitted than for those whose treatment was completed within the ED. It should be noted that the patient length of stay was not controlled in this analysis.

Table 7. The TAT and test volume characteristics for Top-10 tests with the highest utilisation for inpatients registered with the DRG of 'Chest Pain' (F74Z) at the four general hospitals (A, D, E and F) compared with equivalent patients within the EDs at the same hospitals. Study period (DRG): January 2008 to December 2013. Study period (MDB): Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F.

Overall – 4 General Hospitals

Median TAT in mins (IQR)
No. of Tests (% of Tests)

	MDB=Circulatory System Not-Admitted; Triage 2-3	MDB=Circulatory System Admitted; Triage 2-3	DRG=Chest Pain (Inpatients)
TROPONIN	55 (46-69) 4886 (20.2%)	57 (47-76) 11547 (16.8%)	57 (45-78) 35027 (21.8%)
EUC	49 (40-64) 4391 (18.2%)	51 (40-68) 10789 (15.7%)	58 (41-87) 25830 (16.0%)
FBC [a]	27 (18-42) 4317 (17.8%)	30 (20-48) 10402 (15.2%)	41 (24-76) 24595 (15.3%)
LFT	52 (42-69) 2312 (9.6%)	54 (42-74) 6928 (10.1%)	57 (42-86) 13922 (8.7%)
CA MG PHOS	50 (41-66) 1978 (8.2%)	54 (42-74) 5515 (8.0%)	65 (46-99) 11784 (7.3%)
PT/INR/APTT	47 (36-65) 1568 (6.5%)	49 (36-66) 5840 (8.5%)	61 (43-91) 11488 (7.1%)
GLUCOSE	49 (38-65) 796 (3.3%)	52 (39-70) 2976 (4.3%)	56 (40-83) 7046 (4.4%)
C-REACTIVE PROTEIN	55 (43-75) 456 (1.9%)	64 (45-110) 1608 (2.3%)	80 (54-121) 4560 (2.8%)
LIPASE	55 (42-77) 512 (2.1%)	60 (43-100) 1372 (2.0%)	61 (42-99) 3392 (2.1%)
D-DIMER LIA	55 (39-82) 522 (2.2%)	64 (44-119) 850 (1.2%)	65 (43-110) 2989 (1.9%)
Overall (All tests)	49 (36-67) 24188 (100.0%)	52 (37-77) 68585 (100.0%)	60 (42-95) 160943 (100.0%)

[a] TAT is calculated on the Automated Differential test

Table 8 shows TAT and test volume characteristics for the Top-10 tests with the highest utilisation for inpatients registered with the 'Chest Pain' DRG (F74Z). It compares the median TAT and variability (as indicated by the IQR) at four of the general study hospitals (the specialist hospitals, B and C, are excluded). When considering inpatients, Hospital A had both the shortest median TAT for the Top-10 pathology tests (56 minutes) and the smallest amount of variability in TAT (IQR: 37-87 minutes).

Overall, the Top-10 pathology tests in Hospital A were processed with the shortest median TAT of 56 minutes; the TAT was 58 minutes at Hospital E, 61 minutes at Hospital D and 65 minutes at Hospital F. Similarly the overall variability, as indicated by the IQR, was smallest for Hospitals A and D (IQR: 37-87 minutes, and IQR: 43-93 minutes, respectively); second smallest for Hospital E (IQR: 41-96 minutes) and greatest at Hospital F (IQR: 45-101 minutes).

Table 8. A comparison between the four study hospitals (A, D, E and F) of the TAT and test volume characteristics for Top-10 tests with the highest utilisation for inpatients registered with the DRG of 'Chest Pain' (F74Z). Study period (DRG): January 2008 to December 2013.

DRG=Chest Pain (Inpatients)

Median TAT in mins (IQR)
No. of Tests (% of Tests)

	A	D	E	F	Overall
TROPONIN	56 (42-76) 9089 (23.6%)	61 (46-84) 4421 (21.2%)	57 (47-76) 11746 (22.2%)	58 (46-78) 9771 (20.1%)	57 (45-78) 35027 (21.8%)
EUC	55 (36-81) 6588 (17.1%)	61 (45-86) 2977 (14.3%)	56 (41-89) 8692 (16.4%)	61 (44-92) 7573 (15.6%)	58 (41-87) 25830 (16.0%)
FBC [a]	37 (23-60) 6166 (16.0%)	34 (19-61) 2921 (14.0%)	36 (22-68) 8287 (15.7%)	62 (32-124) 7221 (14.8%)	41 (24-76) 24595 (15.3%)
LFT	57 (40-86) 2945 (7.6%)	62 (46-87) 2109 (10.1%)	57 (42-89) 5055 (9.6%)	57 (42-82) 3813 (7.8%)	57 (42-86) 13922 (8.7%)
CA MG PHOS	73 (51-107) 2188 (5.7%)	62 (46-90) 1991 (9.6%)	70 (46-107) 3761 (7.1%)	60 (44-91) 3844 (7.9%)	65 (46-99) 11784 (7.3%)
PT/INR/APTT	53 (37-76) 1647 (4.3%)	63 (44-91) 1673 (8.0%)	60 (41-95) 4069 (7.7%)	66 (46-93) 4099 (8.4%)	61 (43-91) 11488 (7.1%)
GLUCOSE	50 (32-76) 1775 (4.6%)	60 (45-84) 1229 (5.9%)	57 (39-93) 1265 (2.4%)	56 (41-83) 2777 (5.7%)	56 (40-83) 7046 (4.4%)
C-REACTIVE PROTEIN	82 (55-132) 637 (1.7%)	73 (52-110) 931 (4.5%)	86 (53-129) 1472 (2.8%)	79 (55-116) 1520 (3.1%)	80 (54-121) 4560 (2.8%)
LIPASE	57 (37-97) 757 (2.0%)	66 (47-101) 533 (2.6%)	61 (43-105) 906 (1.7%)	60 (43-95) 1196 (2.5%)	61 (42-99) 3392 (2.1%)
D-DIMER LIA	52 (37-78) 808 (2.1%)	86 (52-199) 320 (1.5%)	59 (40-102) 913 (1.7%)	78 (53-134) 948 (1.9%)	65 (43-110) 2989 (1.9%)
Overall (All tests)	56 (37-87) 38585 (100.0%)	61 (43-93) 20811 (100.0%)	58 (41-96) 52890 (100.0%)	64 (45-101) 48657 (100.0%)	60 (42-95) 160943 (100.0%)

[a] TAT is calculated on the Automated Differential test

SECTION X: DEMAND MANAGEMENT AND GUIDELINES AND TEST SELECTION IN THE ED

INTRODUCTION

Pathology test ordering patterns continue to be a topic of much discussion. Although it is generally understood that quality use of pathology is associated with choosing the right test at the right time for the right patient and for the right clinical condition[8], the identification of problems related to over-utilisation can be complex. Many EDs have developed guidelines that specify the types of presenting problems, or potential diagnoses, that justify the use of different pathology tests. For example, the Sensible Test Ordering Practice guideline [65] classified pathology tests according to a 'traffic-light' classification, where 'green' tests such as EUC, FBC and INR/APTT tests are unrestricted, 'orange' tests such as Troponin, CRP and Creatine Kinase (CK), should be ordered less frequently and must be counter-signed by a registrar or specialist and 'red' tests such as Immunology tests, Urinary Drug Screen tests and Lipids are not for routine ordering in the ED and must be authorised by a specialist.

In 2013, the Royal College of Pathologists Australasia (RCPA) and the Australasian College for Emergency Medicine (ACEM) released the 'Guideline on Pathology Testing in the Emergency Department' that included a matrix of common presenting problems in the ED and specified which pathology tests are usually recommended, can be considered after consultation with a supervisor, or are not generally indicated.[66]

METHODS

The clinical scenarios leading up to three different pathology tests were examined. The CRP test was chosen because it was not coded as 'recommended' for any patient presentation in the RCPA/ACEM guideline document.[66] CK was chosen as it is only 'recommended' for snake bite presentations and to be 'considered' for Overdose (significant) presentations.[66] Troponin tests were chosen as they are 'recommended' when there is shortness of breath or chest pain[66] because it is currently recognised as the best test for a very specific type of ED presentation: where there is suspicion of Acute Myocardial Infarct (AMI).[67-69]

The ED information system recorded the patient presenting problem using a free-text field where the triage nurse typed a brief short-hand description of their assessment of the patient upon presentation. A high degree of variability was found in the terminology, syntax and level of detail that was recorded for ED presentations, so it was impossible to use computer algorithms to aggregate ED presentations into reliable and coherent groups. Therefore, it was decided to use the MDB category (of which there are 27 discrete categories) for each ED presentation as a proxy for the ED presenting problem.

For each of the three tests analysed (CRP, CK and Troponin), all of the ED presentations where the test was ordered within the first test order episode of the ED presentation were selected, and the MDB used to categorise the type of patient illness. The overall proportion represented by each MDB was plotted collapsed across all EDs, in addition to the proportions at each individual ED.

RESULTS

C-REACTIVE PROTEIN

Figure 13 shows the distribution of MDBs for which CRP was ordered in the first test order episode of the ED presentation. Patients presenting with digestive system illnesses accounted for the highest proportion of patients (25%) who had a CRP test ordered in the first test order episode. Patients with digestive system illnesses accounted for 25% of ED presentations with CRP in the first test order episode at EDs D, E and F, 19.5% of ED presentations at ED A and 29.6% at ED C. Patients presenting with circulatory, neurological and respiratory system illnesses and system infection/parasites each had similar proportions of CRP tests ordered in the first test order episode in ED (approximately 10-15%) at all of the EDs apart from ED C, where CRP was much less frequently ordered in the first test order episode for circulatory system and neurological illnesses. The Top-10 MDBs accounted for 87-89% of all ED presentations for which CRP was ordered in the first test order episode.

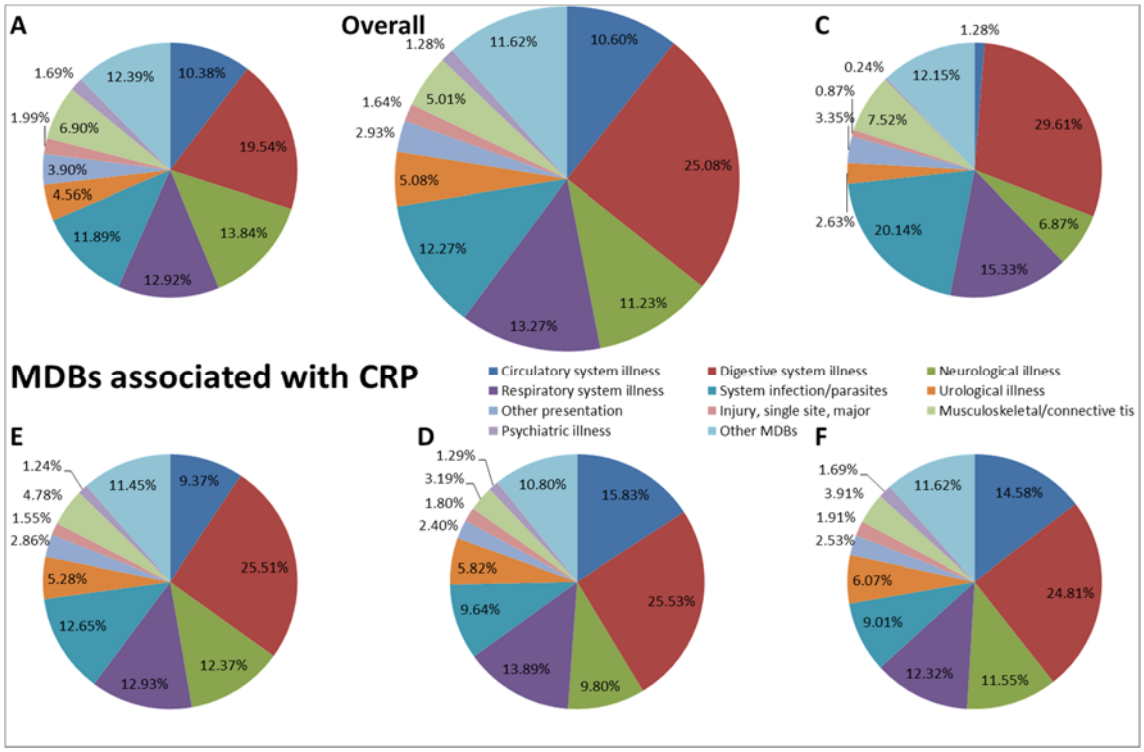

Figure 13. The Major Diagnostic Block (MDB) categories, and proportions, assigned to ED patients who received a C-Reactive Protein (CRP) test request during the first test order episode upon presenting at each of the five study EDs. Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

CREATINE KINASE

Figure 14 shows the distribution of MDBs for which CK was ordered in the first test order episode of the ED presentation. Patients presenting with neurological illnesses accounted for the highest proportion of patients (23%) who had a CK test ordered in the first test order episode; the proportion was even higher at EDs E and F (26.5% and 27.7%, respectively). At ED C, however, ED patients presenting with musculoskeletal/connective tissue illnesses accounted for a greater proportion (29.4%) of ED presentations

with CK tests in the first test order episode than patients presenting with neurological illnesses (18.5%). Similarly, at ED D, patients presenting with circulatory system illnesses accounted for a greater proportion (26.9%) of ED presentations with CK tests in the first test order episode than patients presenting with neurological illnesses (17.1%). The Top-10 MDBs accounted for 85-94% of all ED presentations for which CK was ordered in the first test order episode.

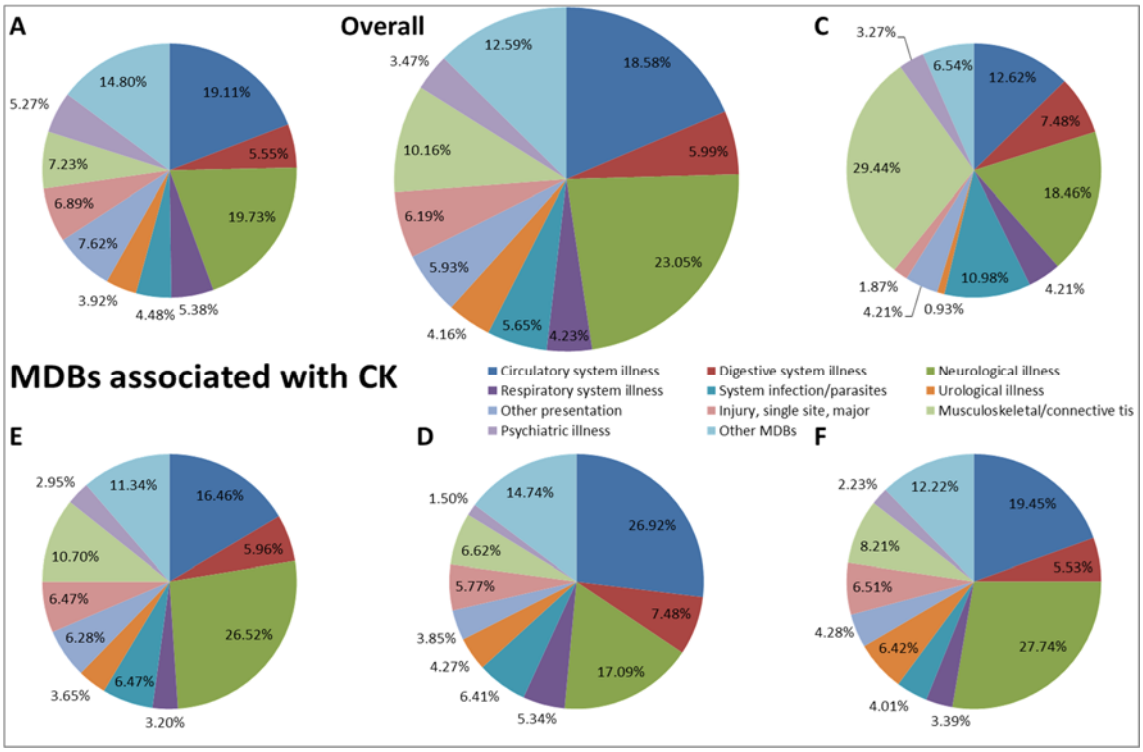

Figure 14. The Major Diagnostic Block (MDB) categories, and proportions, assigned to ED patients who received a Creatine Kinase (CK) test request during the first test order episode upon presenting at each of the five study EDs. Study period was Jul 2009 to Dec 2013 at EDs A, D, E, and F, and Jul 2008 to Dec 2013 at ED C.

TROPONIN

Figure 15 shows the distribution of MDBs for which Troponin was ordered in the first test order episode of the ED presentation. Unsurprisingly, given its use in a very specific domain of clinical presentations, Troponin testing has a relatively unique clinical profile. Overall, ED patients presenting with circulatory system illnesses accounted for the greatest proportion (62.2%) of ED presentations where Troponin tests were ordered in the first test order episode. Circulatory system illness presentations accounted for 58.6% of ED presentations with Troponin tests in the first test order episode at ED D, while they accounted for 68.4% at ED C. ED patients presenting with respiratory system illnesses were the group of patients accounting for the second highest proportion of Troponin tests in the first test order episode, accounting for 8.9-12.2% of all ED presentations with Troponin tests in the first test order episode. Patients with digestive system and neurological illnesses represented similar proportions (6-8%) at all EDs, while the remaining MDBs accounted for fewer than 2% ED presentations where a Troponin test was ordered in the first test order episode.

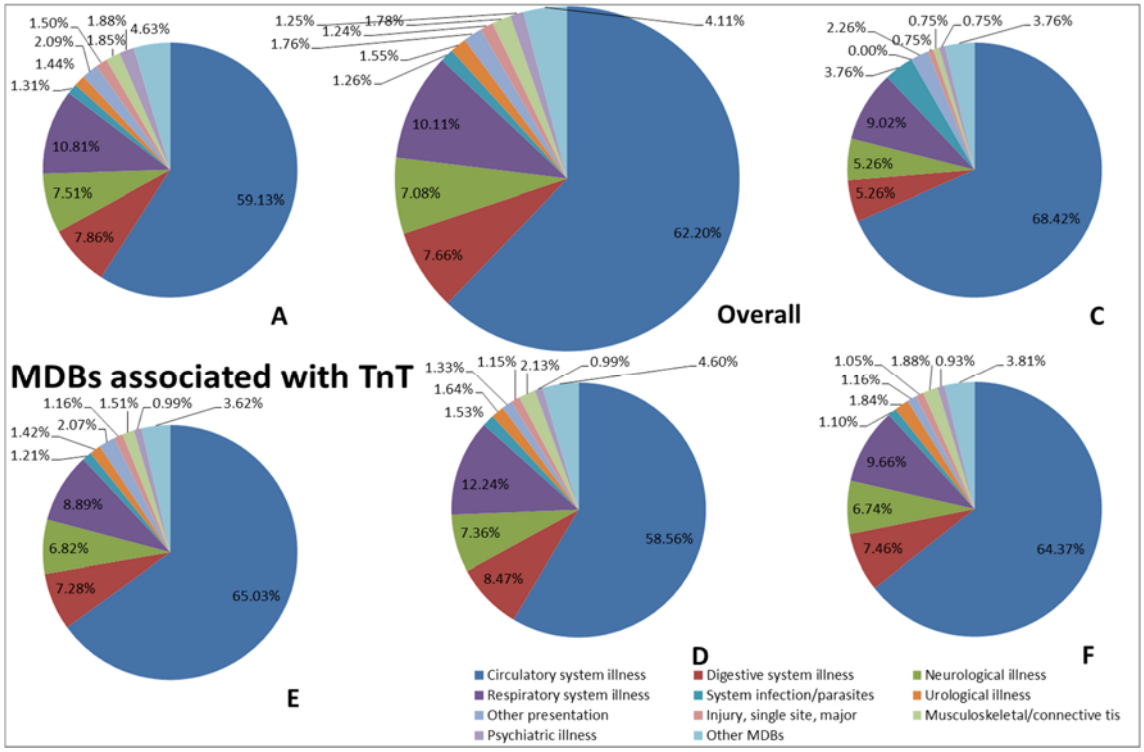

Figure 15. The Major Diagnostic Block (MDB) categories, and proportions, assigned to ED patients who received a cardiac Troponin (TnT) test request during the first test order episode upon presenting at each of the five study EDs. Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

Test Selection in the First Test Order Episode in the ED

METHODS

The Top-5 MDBs with the highest pathology test utilisation were selected and the Top-10 pathology tests that were ordered for ED presentations in those five MDBs assessed. It was hypothesised that a comparison of the proportion of pathology testing accounted for by each Top-10 test, across the five MDBs, could show whether pathology test selection in the first test order episode is mainly guided by differences between the MDBs or whether a broadly similar battery of pathology tests is ordered for the patient regardless of the type of illness they are presenting with.

The initial analyses used only first-test-order episodes in the acute/resuscitation care area of the ED to ensure that the test order was associated with the diagnosis-phase of the ED presentation. The linkage process for this 'ED patient movements dataset' is described in detail in SECTION V: METHODS. However, the 'ED patient movements dataset', that allowed the initial analyses to focus on the acute/resuscitation care area within the ED, described only one month of ED presentations at all EDs. The analysis was subsequently repeated using the larger 'Pathology utilisation dataset' (which covered a much longer study period: July 2009 to December 2013 for EDs A, D, E and F, and July 2008 to December 2013 for ED C). For this analysis only pathology test orders in the first test order episode were considered but without any restriction on the location within the ED where the test was ordered.

RESULTS

ALL MDBS (ACUTE/RESUSCITATION AREA ONLY)

Figure 16 shows the Top-5 MDBs with the highest number of presentations at the study EDs and, for each MDB, shows the tests that were ordered in the first test order episode for patients located in the acute/resuscitation area of any of the study EDs in December 2013. EUC and FBC tests were the most frequently ordered tests for all Top-5 MDBs. EUC tests accounted for 14.9-19.5% of tests depending on the MDB, while FBC tests accounted for 13.7-19.1% of tests depending on the MDB. LFT and Calcium Magnesium Phosphate (CA MG PHOS) were also prominent tests across all MDBs, accounting for 9.3-13.1% and 5.7-10.2% of all tests, respectively. There were two striking examples where test selection practices for MDBs were unique to that MDB. As Troponin is recommended when a patient presents with shortness of breath or chest pain, it is unsurprising that Troponin tests accounted for 16.2% of tests for Circulatory system illness ED presentations, while it accounted for 1.0-5.1% of tests for the remaining four Top-5 MDBs. While the Top-10 tests accounted for 81.4-89.9% of tests in the first four MDBs, the System infection/parasites MDB was unique in that the Top-10 tests accounted for less than two-thirds of the tests.

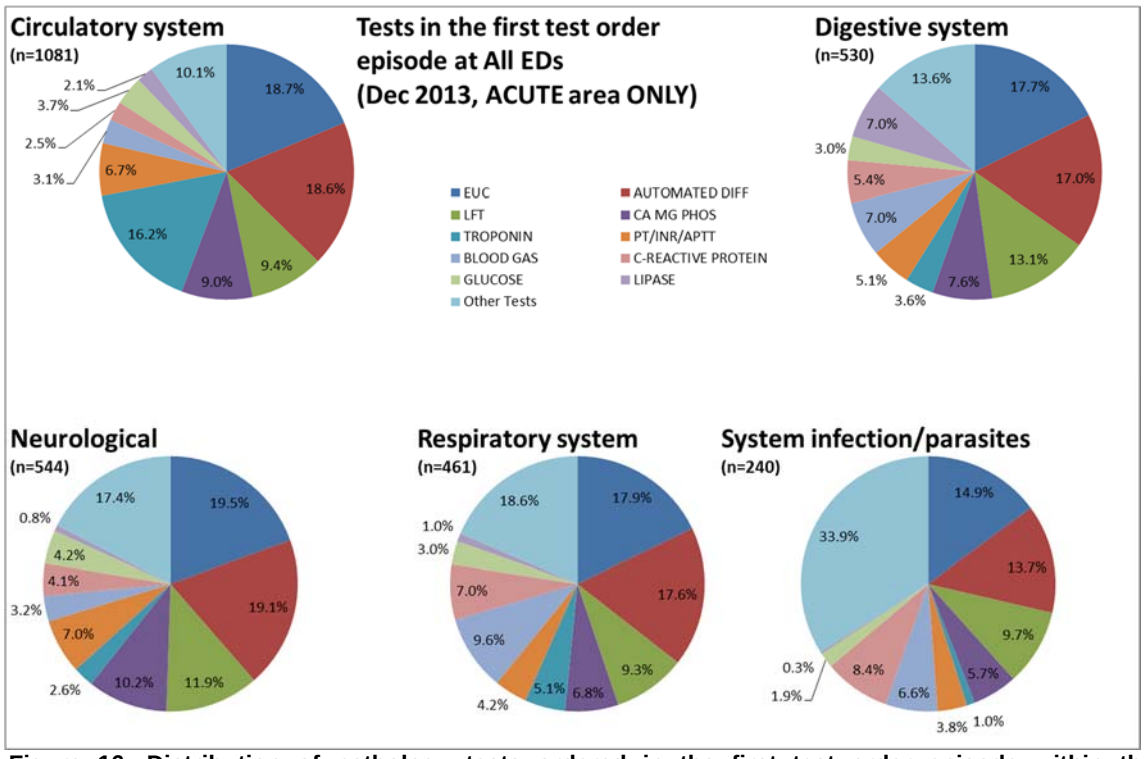

Figure 16. Distribution of pathology tests ordered in the first test order episode within the acute/resuscitation area of the ED (A, C, D, E and F) for each of the Top-5 Major Diagnostic Block (MDB) categories with the highest number of presentations at the study EDs. The numbers in parentheses show the number of ED presentations, for each MDB, where at least one pathology test was ordered from within the acute/resuscitation area of the ED.

ALL MDBS (ALL ED AREAS)

Figure 17 shows the Top-5 MDBs with the highest number of presentations at the study EDs and, for each MDB, shows the tests that were ordered in the first test order episode for all patients located (regardless of the location in the ED where they were located). Unlike Figure 16, which presents results for December 2013,

Figure 17 shows results for a much longer study period (July 2009 to December 2013 for EDs A, D, E and F, and July 2008 to December 2013 for ED C).

It is noteworthy that the distribution of tests when considering the first test order episode but ignoring the patient location (Figure 17) is broadly similar to the initial analysis that considered patients in the acute/resuscitation area only (Figure 16). One difference between the restricted analysis (Figure 16) compared to when considering the entire ED (Figure 17), is that Blood Gas tests account for more tests in the Respiratory system illness MDB than for other Top-5 MDBs, but this difference is not evident when considering only the acute/resuscitation area of the ED.

Since this distribution of tests is broadly similar, the remaining analyses of the individual MDBs will use the larger dataset covering 4.5 years in EDs A, D, E and F, and 5.5 years in ED C.

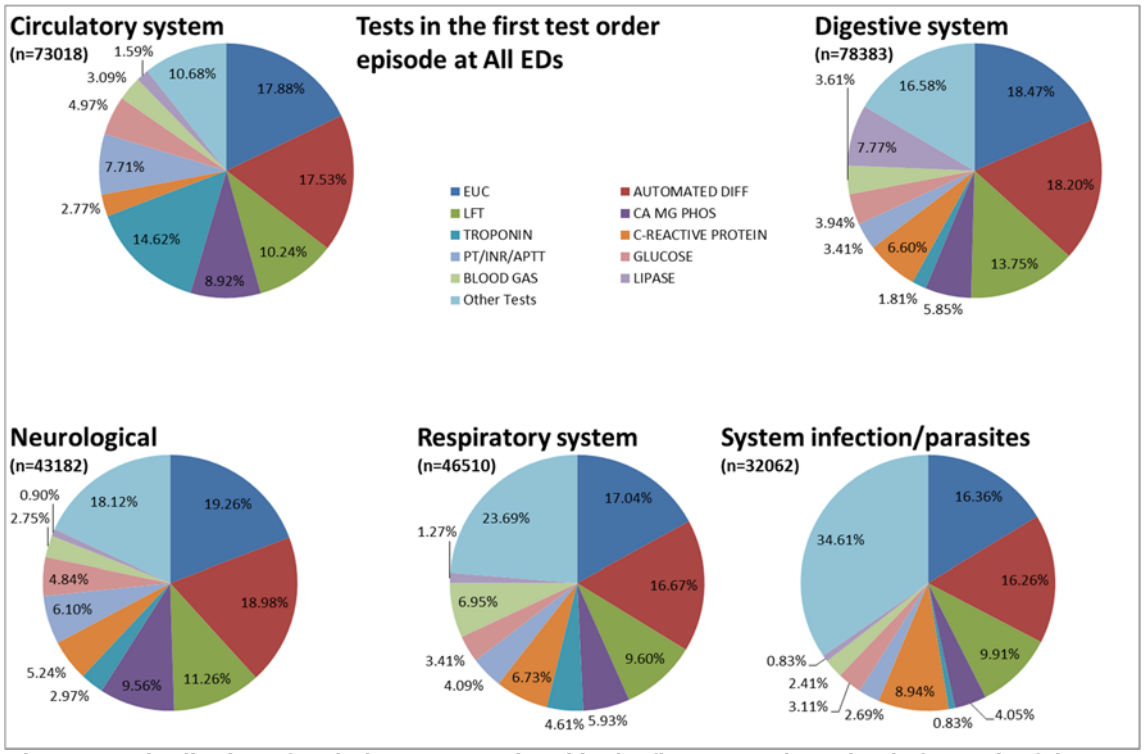

Figure 17. Distribution of pathology tests ordered in the first test order episode for each of the Top-5 Major Diagnostic Block (MDB) categories with the highest number of presentations at the study EDs (A, C, D, E and F). The numbers in parentheses show the number of ED presentations, for each MDB, where at least one pathology test was ordered.

This same method was used to select a single high-volume MDB and compare which pathology tests are ordered in the first test order episode at each of the five study EDs.

Figure 18 shows the tests that were ordered in the first test order episode for all patient presentations classified with an MDB of Circulatory system illness at the five study EDs. The distribution of tests is similar at EDs A, D, E and F (all general hospital EDs), where the Top-10 tests accounted for 88.2-90.6% of all tests. However, in ED C (childrens' hospital ED) the distribution of tests was different to the other ED, with EUC, FBC, LFT, CA MG PHOS and Troponin accounting for only 41% of tests, compared to 69% at all EDs.

However, it should be noted that, compared to the other EDs and relative to other types of illnesses, ED C had very few Circulatory system illness presentations.

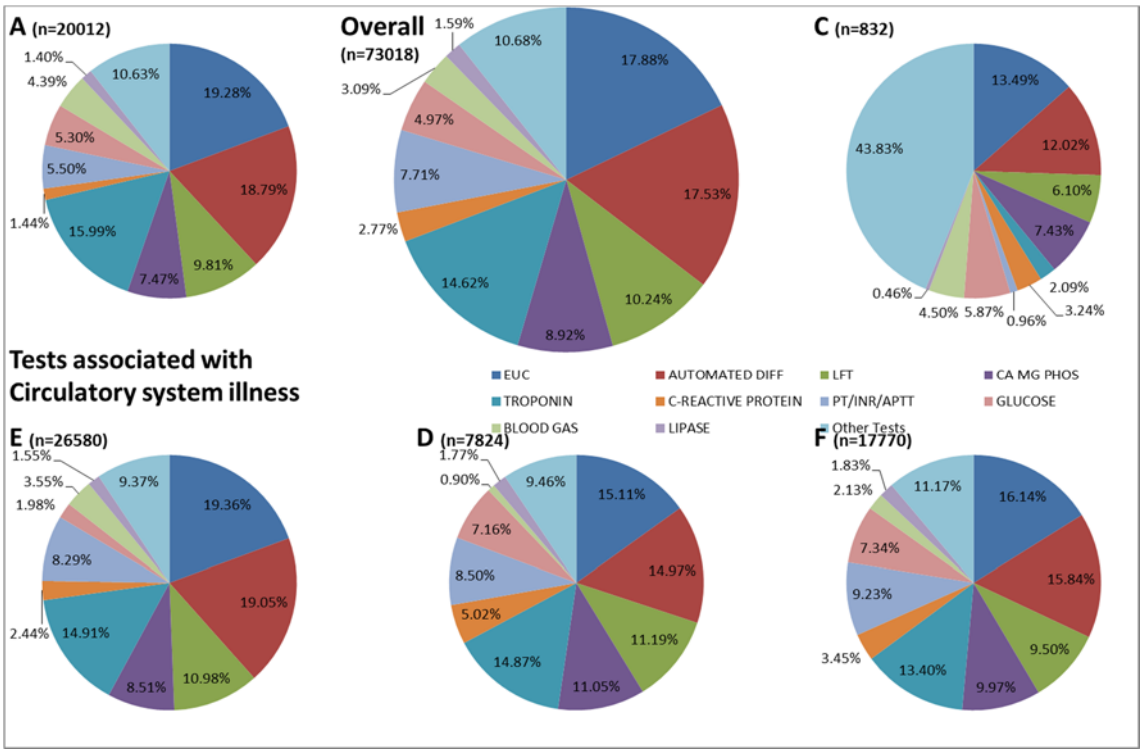

Figure 18. Distribution of pathology tests ordered in the first test order episode for ED patients presenting at the five study EDs (A, C, D, E and F) classified with an MDB of 'Circulatory system illness'. The numbers in parentheses show the number of ED presentations where at least one pathology test was ordered.

SECTION XII: CARESET UTILISATION FOR INPATIENTS AND IN THE ED

INTRODUCTION

The provision of Caresets, also known as 'Order Sets', is seen as an important means of improving the quality of the choice of laboratory tests that is relevant to patient conditions and their circumstances. This form of clinical decision support can be a means of helping to ensure that required tests are not missed or conversely that tests are not ordered unnecessarily.[70,71]

The aim of this study was to investigate what Caresets had been setup in the study hospitals, what tests were included in the most frequently used Caresets and the frequency that these Caresets were used. The second aim was to investigate which DRGs (for inpatients) and MDBs (for Emergency patients) were associated with the greatest use of Caresets for pathology test ordering.

METHODS

In the study hospitals, the Cerner EMR system included Caresets that contained pathology tests (or test sets) and imaging procedures grouped together according to common clinical situations where their use is recommended.

Analyses used the 'Careset utilisation dataset'. This data file described the test orders for pathology tests and radiology procedures ordered within the six study hospitals for the month of September 2013. The linkage process for this 'Careset utilisation dataset' is described in SECTION V: METHODS.

RESULTS

Table 9 shows the Top-10 most frequently ordered Caresets, the contents of each Careset and the frequency that each Careset was ordered at the study hospitals. Out of 289,417 tests, 34,008 were ordered as part of a Careset, accounting for 11.8% of tests. 'Blood Group and Antibody Screen', containing Blood Group and Antibody Screen, BBT History and Anti-D Antibody, was the most frequently ordered Careset. This Careset was ordered 4,441 times, accounting for 51.2% of all Caresets ordered. The Top-10 most frequently ordered Caresets accounted for 88.4% of all Caresets ordered in the six study hospitals. However, only 11.8% of all tests were ordered as part of a Careset.

Table 9. A list of the Top-10 most frequently ordered Caresets, collapsed across the six study hospitals, the tests contained within each Careset the overall frequency with which that Careset was ordered and total number of tests ordered within the Careset. Analysis was performed for September 2013.

Rank	Careset Name	Careset Contents	Total No. of Caresets	Total No. of Tests
1	Blood Group and Antibody Screen	-Blood Group and Antibody Screen -BBT History and Anti-D Antibody	4441	13712
2	Crossmatch (Add-on)	-Crossmatch Order -Blood Product Red Cells Order	1816	4062
3	Vitamin B12, Folate & Red Cell Folate	-FBC -Folate -Red Cell Folate -Vitamin B12	799	3237
4	Blood Group, Screen and Crossmatch	-Blood Group and Antibody Screen -BBT History and Anti-D -Crossmatch Order -Blood Product Red Cells Order	601	3035
5	ICU Order Set	-FBC -EUC -Liver Function Tests (LFT) -CA MG PHOS -Coagulation Profile -X-Ray Chest -Arterial Blood Gas	271	1558
6	Urine Drug Screen	-Urine Cocaine Level -Urine Cannabinoids -Urine Benzodiazepine -Urine Barbiturate Level -Urine Amphetamine -Urine Opiates	227	1367
7	Haematology Order Set	-Blood Group and Antibody Screen -FBC -EUC -LFT -CA MG PHOS -Coagulation Profile -Glucose -Urate -Lactate Dehydrogenase -CRP	149	1553
8	Direct Antiglobulin Tests	-BBT History -Direct Antiglobulin Test	142	292
9	Protein Electrophoresis w/ Albumin	-Protein EPG -Protein -Albumin	123	418
10	Neonatal Blood Group and DAT	-BBT History -Direct Antiglobulin Test -Neonatal Blood Group	106	318
	Overall (Top-10 Caresets) [a]		8675 (88.4%)	29552 (86.9%)
	Overall (All Caresets) [b]		9812	34008 (11.8%)
	Overall (All Tests)			289417

[a] Number of Top-10 Caresets ordered and (proportion of All Caresets accounted for); and total number of tests ordered within the Careset and (proportion of All tests ordered within a Careset)

[b] Number of All Caresets ordered; and total number of tests ordered within All Caresets and (proportion tests ordered within Caresets out of All Tests ordered)

Table 10 shows the Top-10 DRGs for inpatients that had the highest volume of Careset utilisation. 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC' was the inpatient DRG with the most number of Caresets ordered at 1,427 (14.2%). However, there were several DRGs where a greater proportion of tests were ordered using Caresets, including 'Neonate, AdmWt >2499g W/O Significant OR Procs W/O Problem' where 40.4% were ordered in Caresets (ranked fifth by frequency of tests ordered in Caresets) and 'Red Blood Cell Disorders W/O Cat or Sev CC' where 39.4% were ordered in Caresets (ranked seventh by frequency of tests ordered in Caresets). The Top-10 DRGs accounting for the highest volume of Careset utilisation only accounted for 19.5% of Careset orders, suggesting that Careset utilisation is spread broadly across many DRGs.

Table 10. The Top-10 DRGs that had the greatest number of tests ordered as part of a Careset, the proportions and volume of tests ordered independently or as part of a careset for each DRG, the proportion of all Careset orders accounted for by Careset orders for this DRG and the cumulative proportion of Careset orders accounted for, at six study Hospitals in the month of September 2013. DRGs are ranked according to raw volume of tests ordered as part of a Careset.

	Non-Careset orders	Careset orders	Careset orders for all DRGs		
DRG	Number (%)	Number (%)	% of Total	Cum. % of Total	Total
Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC	8594 (85.8%)	1427 (14.2%)	4.2%	4.2%	10021
Vaginal Delivery	2332 (66.1%)	1196 (33.9%)	3.5%	7.7%	3528
Rehabilitation W/ Cat CC	9462 (91.9%)	836 (8.1%)	2.5%	10.2%	10298
Haemodialysis	3897 (84.2%)	729 (15.8%)	2.1%	12.3%	4626
Neonate, AdmWt >2499g W/O Significant OR Procs W/O Problem	665 (59.6%)	451 (40.4%)	1.3%	13.6%	1116
Acute Leukaemia W/ Cat CC	1767 (79.9%)	445 (20.1%)	1.3%	14.9%	2212
Red Blood Cell Disorders W/O Cat or Sev CC	645 (60.6%)	420 (39.4%)	1.2%	16.2%	1065
Caesarean Delivery W/ Sev CC	707 (62.8%)	419 (37.2%)	1.2%	17.4%	1126
Caesarean Delivery W/ Cat CC	1182 (75.8%)	378 (24.2%)	1.1%	18.5%	1560
Red Blood Cell Disorders W/ Cat or Sev CC	751 (68.6%)	343 (31.4%)	1.0%	19.5%	1094
Overall (All DRGs)	255409	34008		100.0%	289417

Table 11 shows the Top-10 MDBs, for emergency patients, that had the highest volume of Careset utilisation. 'Digestive system illness' was the MDB in the EDs with the greatest number of Caresets ordered at 1,203 (9.1%). However, as was the case for DRGs, several MDBs had a greater proportion of tests ordered using Caresets, including 'Blood/immune system illness' where 30.5% were ordered in Caresets (ranked second by

frequency of tests ordered in Caresets) and 'Obstetric illness' where 29.5% were ordered in Caresets (ranked eighth by frequency of tests ordered in Caresets). The case of MDBs, even more so than DRGs, is marked by a spread of Careset usage across many MDBs, with the Top-10 MDBs accounting for only 15.8% of all Caresets ordered.

Table 11. The Top-10 MDBs that had the greatest number of tests ordered as part of a Careset, the proportions and volume of tests ordered independently or as part of a careset for each MDB, the proportion of all Careset orders accounted for by Careset orders for this MDB and the cumulative proportion of Careset orders accounted for, at five study Hospitals (A, C, D, E and F) in the month of September 2013. MDBs are ranked according to raw volume of tests ordered as part of a Careset.

MDB	Non-Careset orders	Careset orders	Careset orders for all MDBs		
	Number (%)	Number (%)	% of Total	Cum. % of Total	Total
Digestive system illness	90.9% (11985)	9.1% (1203)	3.5%	3.5%	13188
Blood/immune system illness	69.1% (1560)	30.9% (698)	2.1%	5.6%	2258
Neurological illness	91.7% (7096)	8.3% (643)	1.9%	7.5%	7739
Circulatory system illness	94.9% (11428)	5.1% (614)	1.8%	9.3%	12042
Psychiatric illness	75.6% (1340)	24.4% (432)	1.3%	10.6%	1772
Injury, multiple sites	81.1% (1788)	18.9% (417)	1.2%	11.8%	2205
System infection/parasites	93.2% (5062)	6.8% (370)	1.1%	12.9%	5432
Obstetric illness	70.5% (882)	29.5% (369)	1.1%	14.0%	1251
Other presentation	86.9% (2331)	13.1% (351)	1.0%	15.0%	2682
Injury, single site, major	91.5% (2890)	8.5% (270)	0.8%	15.8%	3160
Overall (All MDBs)	255409	34008		100.0%	289417

SECTION XIII: PATIENT OUTCOME – EMERGENCY DEPARTMENT (ED) LENGTH OF STAY

AIMS

This analysis aimed to examine:

- the effect of pathology and imaging testing on ED LOS.
- the effect of pathology tests from different departments and imaging procedures of different modalities.
- the mode of separation from the ED on patients' ED LOS.

DATA

The data included all the ED patients who presented at Hospital A during the 2013 calendar year (1st January to 31st December 2013) along with data describing the pathology tests and imaging procedures ordered during the ED presentation for those patients. Figure 19 shows the scope and relationship of the component data sources; the chequered area represents the data included in the analysis. The linkage process for this 'ED LOS dataset' is described in SECTION V: METHODS.

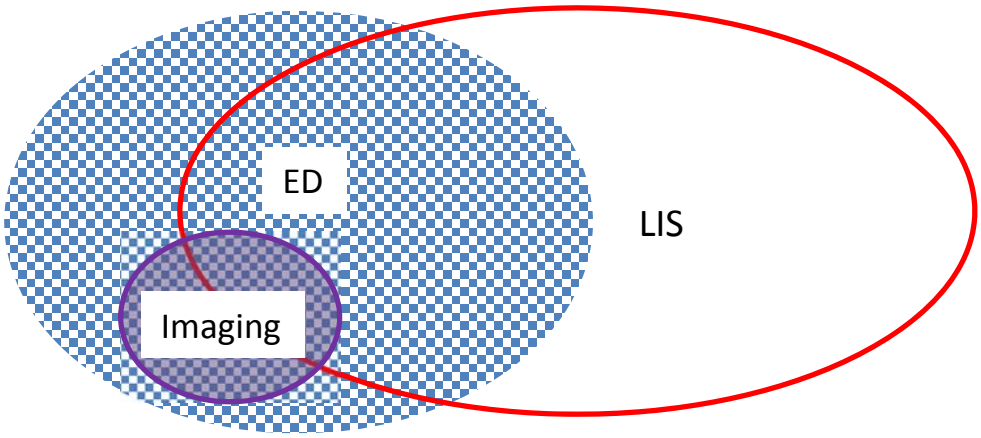

Figure 19. The chequered area shows data included in the analysis.

ED PRESENTATIONS

PRESENTATIONS

In total, there were 35,755 patients with 49,428 unplanned ED presentations at Hospital A during 2013. Of these patients, 78.2% (n=27,964) had one unplanned ED presentation while 21.8% (n=7,791) had multiple unplanned ED presentations. Overall, the treatment was completed within the ED for 55.1% of ED presentations ; the patient was discharged from the ED as a hospital inpatient in 38.3% of ED presentations; and in the remaining presentations (~6.6%) the patient either died within the ED, or left at their own risk or for an unknown reason.

ED LENGTH OF STAY (LOS)

It can be seen in Figure 20 that the median ED LOS was 214 minutes, the IQR was 133 to 325 minutes and that the distribution of ED LOS is skewed to the right. Figure 21 shows that ED LOS for ED presentations were distributed in a similar way when stratified by the mode of separation.

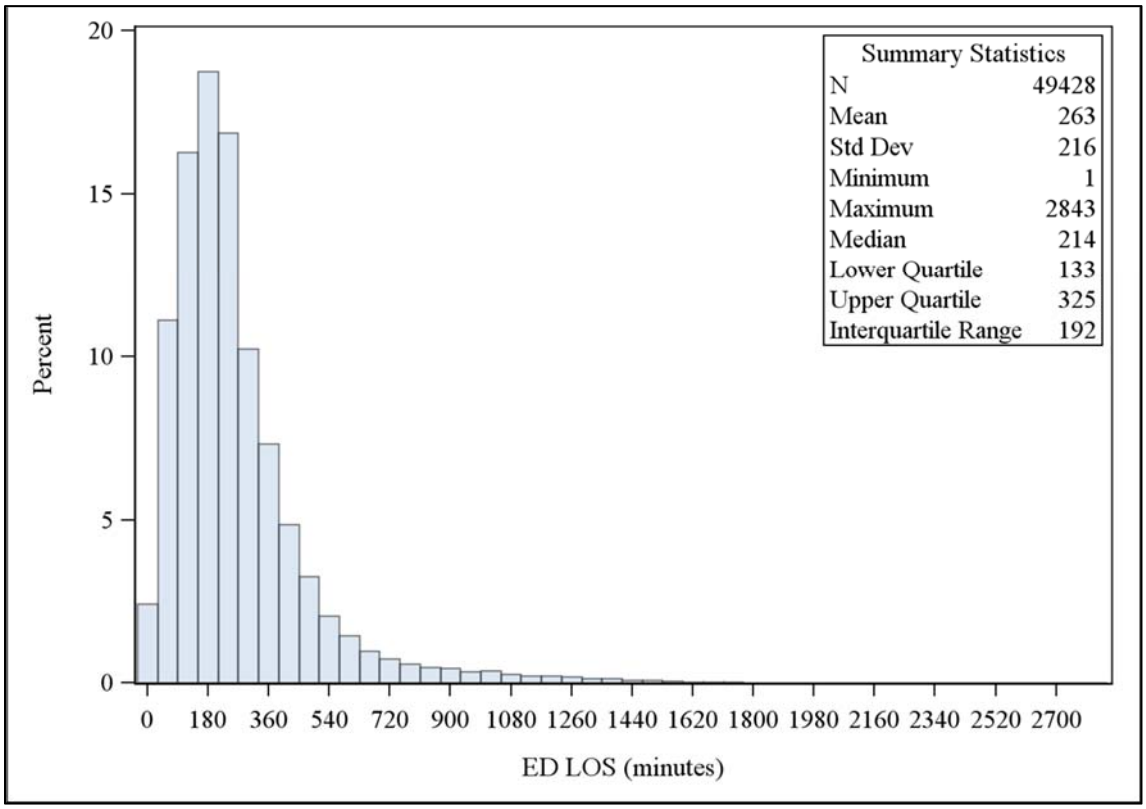

Figure 20. Distribution of ED LOS.

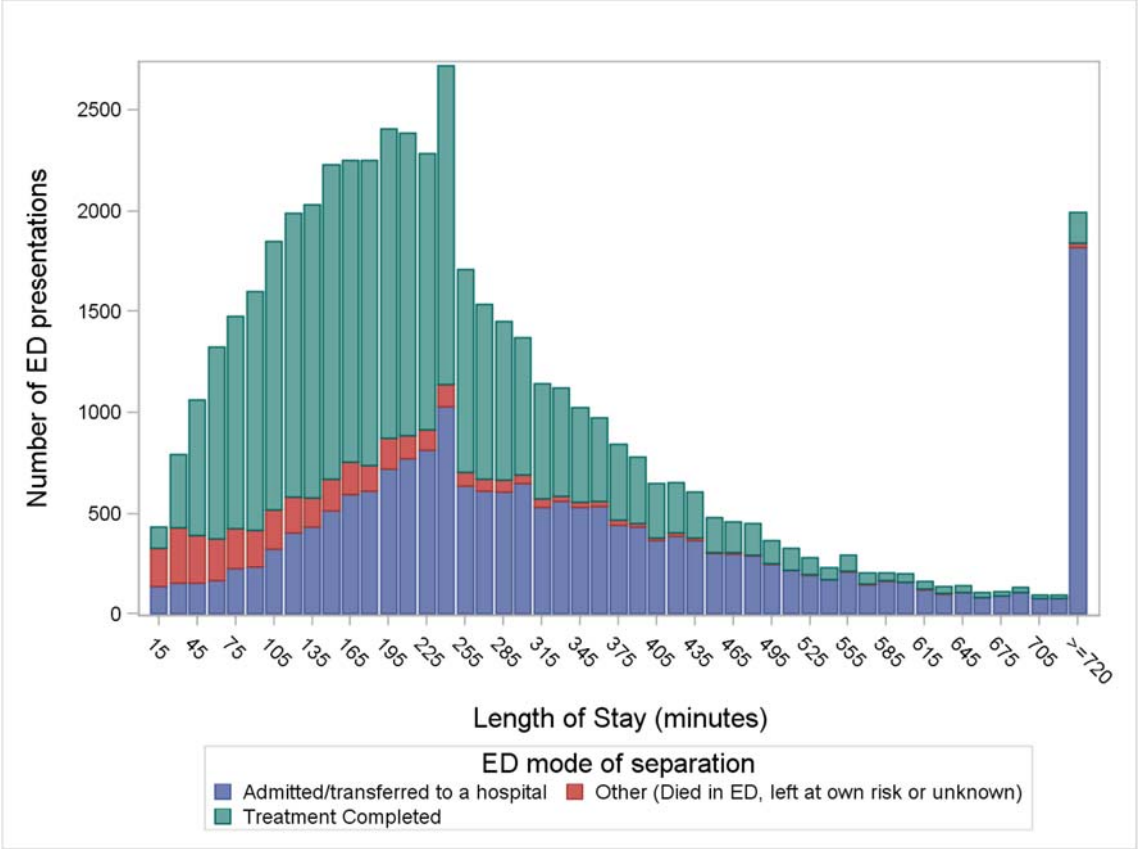

Figure 21. Distribution of ED LOS by the mode of separation.

PATHOLOGY TESTS

There were 150,710 pathology tests ordered for 27,888 ED presentations (56.4% of all ED presentations). The number of test order episodes varied from 1 to 13 per ED presentation and the number of pathology tests from 1 to 46 per ED presentation. The majority of tests were conducted in the Clinical Chemistry (62.6%), Haematology (23.2%) and Microbiology (10.3%) departments.

IMAGING PROCEDURES

A total of 16,496 imaging procedures were ordered for 13,631 ED presentations (27.6% of all ED presentations). The number of imaging procedures varied from 1 to 8 procedures per ED presentation. The majority of imaging procedures were X-Ray (82.7%), CT (14.8%) and ultrasound (2.5%).

DESCRIPTIVE STATISTICS: ED LOS AND PATHOLOGY AND IMAGING TESTING

DESCRIBING THE ROLE OF PATIENT AND ED PRESENTATION CHARACTERISTICS AND PATHOLOGY TESTING AND IMAGING PROCEDURES ON ED LOS

Table 12 shows that overall, the median LOS for ED presentations that featured pathology tests but did not feature imaging procedures (275 minutes, IQR: 194-415), or that featured both pathology tests and imaging procedures (281 minutes, IQR: 207-389) were longer than those with imaging procedures only (160 minutes, IQR: 102-229) or no pathology tests or imaging procedures (133 minutes, IQR: 75-204).

When examining ED presentations across various patient demographics and visiting characteristics, differences in the proportion of presentations and median LOS in different age groups, gender, mode of

separation, triage, ED arrival time, day of week and season were found. Of the patients who had at least one pathology test during their ED presentation (but no imaging procedures), more were eventually admitted as hospital inpatients (61.6%) than had their treatment completed within the ED (36.4%); the median ED LOS of the admitted patients was also longer (333 minutes) than it was for patients whose treatment was completed within the ED (222 minutes). On the other hand, of the patients who had at least one imaging procedure but did not have any pathology tests during their ED presentation, the majority (88.5%) had their treatment completed within the ED, while only 8.7% were eventually admitted as hospital inpatients. As was the case for the 'pathology tests only' group, the patients who were eventually admitted had a longer median ED LOS (196 minutes) than the patients whose treatment was completed within the ED (156 minutes).

DESCRIBING THE ROLE OF ED MODE OF SEPARATION AND PATHOLOGY TEST DEPARTMENTS AND IMAGING PROCEDURE MODALITIES ON ED LOS

ED presentations involving pathology testing experienced a longer median ED LOS than those without any pathology testing. When considering imaging procedures, the pattern is less clear. Patients who had imaging procedures during their ED stay and were eventually admitted as hospital inpatients had shorter ED LOS than those without imaging procedures. On the other hand, patients who had imaging procedures but whose treatment was completed within the ED, experienced longer ED LOS than those who did not have any imaging procedures. When considering individual modalities, this pattern was evident for patients who had X-Ray procedures, but not for patients who had CT or ultrasound procedures.

While these baseline characteristics reveal a number of relationships between the presence of pathology tests (and imaging procedures) and the patient's ED LOS, it is important to note that this only provides evidence of a correlation between measures and does not constitute evidence for causation. It is possible, likely in fact, that the presence of pathology tests during an ED presentation and longer median ED LOS are both caused by other factors such as the complexity of the patient's illness.

Table 12. Baseline characteristics according to testing obtained

	Median LOS in minutes (IQR) No. of presentations (column % in each variable)			
	Pathology tests only	**Imaging procedures only**	**Both**	**None**
Overall (row %)	275 (194-415) N=20555 (41.6%)	160 (102-229) N=6303 (12.8%)	281 (207-389) N=7321 (14.8%)	133 (75-204) N=15177 (30.7%)
Age group (years)				
<18	250 (182-364) N=246 (1.2%)	129 (86-195) N=216 (3.4%)	256 (194-362) N=49 (0.7%)	127 (69-204) N=405 (2.7%)
18-34	237 (174-345) N=5646 (27.5%)	151 (94-222) N=2813 (44.6%)	274 (200-383) N=1260 (17.2%)	130 (74-200) N=6455 (42.5%)
35-49	251 (180-377) N=4087 (19.9%)	156 (103-226) N=1447 (23.0%)	270 (196-377) N=1386 (18.9%)	134 (76-208) N=3854 (25.4%)
50-64	285 (200-430) N=3334 (16.2%)	162 (107-229) N=913 (14.5%)	273 (203-385) N=1460 (19.9%)	138 (75-205) N=2309 (15.2%)
65-79	313 (216-463) N=3654 (17.8%)	191 (128-252) N=558 (8.9%)	294 (212-405) N=1447 (19.8%)	140 (79-208) N=1356 (8.9%)
>79	340 (230-491) N=3588 (17.5%)	203 (139-271) N=356 (5.6%)	290 (219-399) N=1719 (23.5%)	139 (75-218) N=798 (5.3%)
Gender				
Male	284 (199-428) N=8942 (43.5%)	156 (100-226) N=3652 (57.9%)	275 (202-381) N=3622 (49.5%)	133 (76-204) N=7836 (51.6%)
Female	268 (190-404) N=11613 (56.5%)	165 (106-234) N=2651 (42.1%)	285 (213-399) N=3699 (50.5%)	133 (74-205) N=7341 (48.4%)
ED mode of separation				
Admitted to hospital	333 (225-497) N=12669 (61.6%)	196 (129-269) N=546 (8.7%)	280 (205-397) N=3098 (42.3%)	165 (83-258) N=2611 (17.2%)
Treatment Completed	222 (167-295) N=7481 (36.4%)	156 (100-226) N=5578 (88.5%)	282 (210-386) N=4130 (56.4%)	134 (82-200) N=10019 (66.0%)
Other (Died in ED, left at own risk or unknown)	201 (131-287) N=405 (2.0%)	154 (100-227) N=179 (2.8%)	277 (206-377) N=93 (1.3%)	96 (42-172) N=2547 (16.8%)
Triage category				
Immediately life threatening (1)	265 (167-465) N=343 (1.7%)	266 (57-475) N=2 (0.0%)	265 (187-389) N=23 (0.3%)	144 (17-257) N=50 (0.3%)
Imminently life threatening (2)	305 (208-473) N=2312 (11.2%)	156 (93-223) N=129 (2.0%)	252 (182-365) N=735 (10.0%)	138 (70-228) N=285 (1.9%)
Potentially life threatening (3)	288 (202-436) N=12042 (58.6%)	181 (120-253) N=1587 (25.2%)	283 (209-395) N=4901 (66.9%)	148 (87-222) N=4347 (28.6%)
Potentially serious (4)	243 (178-354) N=5518 (26.8%)	155 (99-226) N=4037 (64.0%)	285 (213-382) N=1606 (21.9%)	135 (79-204) N=8167 (53.8%)
Less Urgent (5)	204 (130-297) N=340 (1.7%)	132 (84-200) N=548 (8.7%)	258 (213-382) N=56 (0.8%)	96 (45-166) N=2328 (15.3%)
(Missing)	144 (80-210) N=8 (0.0%)	38 (22-157) N=3 (0.0%)	257 (119-430) N=4 (0.1%)	33 (9-86) N=57 (0.4%)
ED arrival time				
1AM–7AM	300 (199-461) N=2281 (11.1%)	170 (106-245) N=398 (6.3%)	324 (222-456) N=848 (11.6%)	126 (69-200) N=1462 (9.6%)
7AM–1PM	272 (194-391) N=6461 (31.4%)	143 (89-217) N=2118 (33.6%)	282 (211-381) N=2510 (34.3%)	128 (71-198) N=4565 (30.1%)
1PM–7PM	264 (189-392) N=6946 (33.8%)	148 (97-217) N=2322 (36.8%)	260 (199-356) N=2440 (33.3%)	126 (73-194) N=5095 (33.6%)
7PM–1AM	285 (199-481) N=4867 (23.7%)	196 (134-263) N=1465 (23.2%)	294 (211-450) N=1523 (20.8%)	151 (84-225) N=4055 (26.7%)

	Median LOS in minutes (IQR) No. of presentations (column % in each variable)			
	Pathology tests only	**Imaging procedures only**	**Both**	**None**
Day of week				
Sun	254 (185-401) N=2910 (14.2%)	144 (98-209) N=1199 (19.0%)	256 (194-364) N=1019 (13.9%)	132 (78-192) N=2361 (15.6%)
Mon	291 (206-437) N=3175 (15.4%)	166 (105-233) N=968 (15.4%)	297 (215-409) N=1114 (15.2%)	138 (77-211) N=2400 (15.8%)
Tue	275 (192-409) N=3081 (15.0%)	172 (106-247) N=823 (13.1%)	287 (208-396) N=1069 (14.6%)	137 (70-210) N=2108 (13.9%)
Wed	293 (199-437) N=2841 (13.8%)	174 (110-256) N=732 (11.6%)	296 (210-410) N=1046 (14.3%)	136 (74-211) N=2096 (13.8%)
Thu	270 (190-411) N=2889 (14.1%)	154 (99-226) N=771 (12.2%)	282 (210-387) N=992 (13.6%)	130 (75-203) N=2006 (13.2%)
Fri	270 (197-402) N=2905 (14.1%)	171 (114-237) N=773 (12.3%)	272 (206-391) N=1017 (13.9%)	131 (72-205) N=2018 (13.3%)
Sat	265 (189-397) N=2754 (13.4%)	148 (98-222) N=1037 (16.5%)	267 (207-365) N=1064 (14.5%)	129 (77-195) N=2188 (14.4%)
Season				
Summer (Dec-Feb)	271 (192-403) N=5355 (26.1%)	170 (108-236) N=1611 (25.6%)	289 (212-396) N=1762 (24.1%)	136 (76-212) N=4147 (27.3%)
Autumn (Mar-May)	286 (197-429) N=5082 (24.7%)	153 (98-226) N=1682 (26.7%)	288 (207-407) N=1797 (24.5%)	128 (74-199) N=3753 (24.7%)
Winter (Jun-Aug)	283 (199-437) N=4980 (24.2%)	166 (107-235) N=1505 (23.9%)	283 (210-389) N=1900 (26.0%)	139 (79-211) N=3417 (22.5%)
Spring (Sep-Nov)	260 (188-391) N=5138 (25.0%)	153 (98-218) N=1505 (23.9%)	266 (199-368) N=1862 (25.4%)	129 (72-197) N=3860 (25.4%)

Table 13. Testing and testing types according to the mode of separation

	Median LOS in minutes (IQR) No. of presentations (column % in each variable)			
	Admitted to hospital	**Treatment Completed**	**Other (Died in ED, left at own risk or unknown)**	**Overall**
Overall (row %)	292 (196-446) N=18932 (38.3%)	185 (117-261) N=27242 (55.1%)	114 (52-196) N=3254 (6.5%)	214 (133-325) N=49428 (100.0%)
Pathology tests				
No	173 (94-261) N=3162 (16.7%)	141 (88-210) N=15622 (57.3%)	99 (44-175) N=2756 (84.7%)	140 (82-213) N=21540 (43.6%)
Yes	320 (220-477) N=15770 (83.3%)	238 (179-330) N=11620 (42.7%)	216 (143-304) N=498 (15.3%)	276 (198-407) N=27888 (56.4%)
Clinical Chemistry tests				
No	176 (98-268) N=3362 (17.8%)	143 (89-211) N=16468 (60.5%)	100 (44-176) N=2793 (85.8%)	142 (84-215) N=22623 (45.8%)
Yes	321 (221-478) N=15570 (82.2%)	242 (185-337) N=10774 (39.5%)	219 (144-310) N=461 (14.2%)	282 (202-412) N=26805 (54.2%)
Haematology tests				
No	183 (102-281) N=3587 (18.9%)	144 (90-213) N=16645 (61.1%)	101 (44-178) N=2817 (86.6%)	144 (85-218) N=23049 (46.6%)
Yes	321 (221-478) N=15345 (81.1%)	243 (185-337) N=10597 (38.9%)	219 (148-308) N=437 (13.4%)	282 (202-413) N=26379 (53.4%)
Microbiology tests				
No	258 (176-396) N=13291 (70.2%)	176 (111-248) N=23880 (87.7%)	111 (49-191) N=3150 (96.8%)	196 (120-289) N=40321 (81.6%)
Yes	376 (259-557) N=5641 (29.8%)	246 (183-347) N=3362 (12.3%)	247 (182-391) N=104 (3.2%)	318 (221-471) N=9107 (18.4%)
Imaging procedures				
No	301 (197-464) N=15288 (80.8%)	174 (110-241) N=17527 (64.3%)	108 (47-190) N=2982 (91.6%)	210 (127-326) N=35797 (72.4%)
Yes	263 (195-378) N=3644 (19.2%)	209 (133-302) N=9715 (35.7%)	189 (113-277) N=272 (8.4%)	222 (148-322) N=13631 (27.6%)
X-Ray procedures				
No	301 (199-461) N=15851 (83.7%)	180 (114-252) N=18554 (68.1%)	110 (47-191) N=3007 (92.4%)	215 (131-332) N=37412 (75.7%)
Yes	254 (191-368) N=3081 (16.3%)	197 (126-281) N=8688 (31.9%)	178 (110-265) N=247 (7.6%)	212 (140-306) N=12016 (24.3%)
CT procedures				
No	290 (193-445) N=17909 (94.6%)	179 (114-251) N=25911 (95.1%)	113 (51-194) N=3222 (99.0%)	209 (129-316) N=47042 (95.2%)
Yes	322 (234-461) N=1023 (5.4%)	329 (242-440) N=1331 (4.9%)	318 (223-444) N=32 (1.0%)	326 (237-447) N=2386 (4.8%)
Ultrasound procedures				
No	292 (196-446) N=18830 (99.5%)	184 (117-259) N=26945 (98.9%)	114 (52-196) N=3249 (99.8%)	213 (132-323) N=49024 (99.2%)
Yes	334 (251-521) N=102 (0.5%)	353 (269-453) N=297 (1.1%)	400 (365-411) N=5 (0.2%)	350 (264-457) N=404 (0.8%)

ED LOS ASSOCIATED WITH PATHOLOGY TESTING AND IMAGING PROCEDURES

DATA

Given that the LOS for patients who died in ED, left at their own risk or other unknown reasons is unlikely to have been affected by pathology and imaging testing, these patients were excluded from examination of ED LOS. Presentations where a triage category was not recorded were also excluded. After excluding those ED presentations, 46,132 ED presentations were included in the ED LOS modelling.

STATISTICAL METHODS

Generalised Estimating Equation Modelling (GEE) was used to take into account the correlation between multiple presentations from the same patients with a log-link function and gamma distribution to fit skewed ED LOS data. All patient demographics and ED presentation characteristics were adjusted in the models and the interactions between variables of interest, i.e. testing characteristics, and the mode of separation were considered. Three different models were applied with different testing characteristics:

- grouping the number of test order episodes (0, 1, 2, or 3+) and number of imaging procedures (0, 1, or 2+).
- with/without pathology tests and imaging procedures.
- with/without pathology tests from different departments and different imaging procedure modalities.

ESTIMATING THE IMPACT OF PATHOLOGY TESTING AND IMAGING PROCEDURES ON ED LOS

IMPACT OF THE NUMBER OF PATHOLOGY TEST ORDER EPISODES AND IMAGING PROCEDURES ON ED LOS

The results in Table 14 show that the number of pathology test episodes was positively associated with ED LOS. This positive association was also observed between the number of imaging procedures and ED LOS, for patients whose treatment was completed in the ED. A similar pattern, however, was not evident for ED patients who were eventually admitted as inpatients.

Table 14. Estimated LOS and 95% CIs for number of pathology test episodes and number of imaging procedures according to the mode of separation.

	Estimated LOS in minutes (95% CIs)		
	Overall	**Admitted**	**Treatment completed**
No. of pathology test episodes			
0	178.8 (173.9-183.8)	186.1 (179.0-193.4)	171.7 (167.5-176.0)
1	272.8 (266.4-279.3)	286.5 (278.7-294.5)	259.7 (253.4-266.2)
2	341.5 (333.2-350.0)	367.9 (357.4-378.6)	317.0 (308.3-325.9)
3–13	436.6 (424.5-449.0)	515.4 (498.7-532.7)	369.8 (356.5-383.6)
No. of imaging procedures			
0	267.0 (260.6-273.6)	335.3 (327.7-343.1)	224.2 (219.0-229.7)
1	340.1 (329.7-350.8)	277.2 (268.8-285.9)	257.2 (251.0-263.6)
2–8	274.2 (268.3-280.2)	343.0 (328.4-358.3)	337.1 (326.2-348.5)

IMPACT OF THE PRESENCE OF PATHOLOGY TESTS AND IMAGING PROCEDURES ON ED LOS

Table 15 shows that utilisation of pathology testing or imaging procedures had a different effect on the ED LOS of admitted patients and treatment completed patients. Pathology testing was associated with a longer ED LOS for both admitted patients (an additional 158.1 minutes) and treatment completed patients (an additional 98.5 minutes) when compared with those ED presentations without any pathology tests. The presence of imaging procedures during the ED presentation was associated with longer ED LOS for patients whose treatment was completed within the ED (an additional 37.7 minutes), but was associated with shorter ED LOS for patients who were admitted as hospital inpatients (44.6 fewer minutes). One possible explanation for this effect is that some imaging procedures may have been ordered for a patient while they were still in the ED with the expectation that the patient would be admitted as a hospital inpatient and the results would facilitate treatment during the inpatient stay.

Table 15. Estimated LOS and 95% CIs with/without pathology tests/imaging procedures according to the mode of separation.

		Estimated LOS in minutes (95% CIs)					
		Overall		Admitted		Treatment completed	
Pathology testing	No	173.3 (168.8-178.0)		185.5 (178.8-192.5)		161.9 (158.2-165.7)	
	Yes	299.2 (292.9-305.5)		343.6 (335.7-351.6)		260.5 (254.8-266.3)	
	Additional ED LOS associated with pathology testing	125.9 (120.2-128.9)	*P* <.0001	158.1 (152.1-163.9)	*P* <.0001	98.5 (96.2-100.8)	*P* <.0001
Imaging procedures	No	227.3 (222.4-232.4)		275.8 (268.7-283.0)		187.4 (183.3-191.7)	
	Yes	228.1 (222.6-233.7)		231.1 (223.8-238.6)		225.1 (220.0-230.3)	
	Additional ED LOS associated with imaging procedures	0.7 (-2.5-3.9)	*P* = 0.7	-44.6 (-51.4--38.0)	*P* <.0001	37.7 (35.0-40.2)	*P* <.0001

IMPACT OF TESTING BY DIFFERENT PATHOLOGY DEPARTMENTS AND IMAGING MODALITIES ON ED LOS

Table 16 shows that the presence of clinical chemistry tests in an ED presentation was associated with a larger increase in ED LOS (an additional 112 minutes) than haematology (an additional 46.1 minutes) or microbiology tests (an additional 63 minutes). The same pattern was observed for both patients who were subsequently admitted as inpatients as well as those whose treatment was completed within the ED. CT and ultrasound testing were associated with increased ED LOS for all ED presentations while X-Ray testing was only positively associated with ED LOS for patients whose treatment was completed within the ED. In addition, for those treatment complete patients, much longer additional ED LOS was associated with CTs (an additional 151.5 minutes) or ultrasound (an additional 160.9 minutes) than X-Rays (an additional 32.8 minutes). This could be because clinicians were more willing to make diagnosis and/or treatment decisions based on their own interpretation of X-Ray images, while preferring to defer those decisions until having received the radiologist's report for CT and ultrasound procedures.

Table 16. Estimated LOS and 95% CIs of different pathology and imaging procedures according to the mode of separation.

		Estimated LOS in minutes (95% CIs)		
		Overall	**Admitted**	**Treatment completed**
Clinical Chemistry	No	275.3 (261.5-289.8)	267.7 (244.9-292.5)	283.2 (271.9-294.9)
	Yes	387.3 (369.2-406.3)	384.3 (353.6-417.6)	390.3 (375.4-405.9)
	Additional ED LOS associated with Clinical Chemistry testing*	112.0 (96.8-126.4)	116.6 (90.0-140.9)	107.1 (92.7-120.9)
Haematology	No	304.3 (289.8-319.5)	296.4 (272.4-322.6)	312.3 (300.1-325.1)
	Yes	350.4 (333.5-368.2)	347.0 (318.5-378.0)	353.9 (340.1-368.2)
	Additional ED LOS associated with Haematology testing*	46.1 (29.9-61.5)	50.5 (22.1-76.4)	41.5 (25.6-56.7)
Microbiology	No	296.5 (284.4-309.2)	281.3 (261.8-302.3)	312.6 (303.2-322.4)
	Yes	359.5 (344.4-375.3)	365.7 (339.8-393.5)	353.5 (341.7-365.8)
	Additional ED LOS associated with Microbiology testing*	63.0 (58.7-67.3)	84.4 (78.0-90.6)	40.9 (35.2-46.5)

		Estimated LOS in minutes (95% CIs)		
		Overall	**Admitted**	**Treatment completed**
X-Ray	No	335.5 (321.8-349.7)	355.6 (331.2-381.8)	316.5 (306.7-326.5)
	Yes	317.8 (304.4-331.9)	289.2 (268.5-311.6)	349.2 (338.1-360.7)
	Additional ED LOS associated with X-Ray procedures*	-17.6 (-22.4--12.9)	-66.4 (-75.2--57.6)	32.8 (28.4-37.1)
CT	No	281.9 (270.7-293.6)	299.6 (279.3-321.4)	265.2 (257.6-273.0)
	Yes	378.2 (361.2-396.1)	343.3 (317.3-371.4)	416.7 (401.5-432.5)
	Additional ED LOS associated with CT procedures*	96.3 (89.6-103.0)	43.7 (31.3-55.5)	151.5 (144.9-157.9)
Ultrasound	No	275.8 (269.0-282.7)	290.7 (281.4-300.3)	261.6 (255.3-268.1)
	Yes	386.6 (359.7-415.5)	353.8 (309.7-404.2)	422.5 (403.5-442.4)
	Additional ED LOS associated with Ultrasound procedures*	110.8 (91.4-129.0)	63.1 (22.6-98.6)	160.9 (150.3-171.1)
	* *P*-values for all the difference are <0.0001			

SECTION XIV: COST PROFILE OF PATHOLOGY AND IMAGING TESTING IN THE ED

INTRODUCTION

Under the ABF model, the ED is reimbursed a fixed amount of money according to a predetermined schedule of payments using the National Weighted Activity Unit (NWAU). Each financial year the National Efficiency Price (NEP) unit value of each NWAU is determined to express the reimbursement in AUD units, in the 2013-2014 financial year the NEP paid to hospitals for each NWAU(13) unit was AUD4,993.[72]

The aim of these analyses was to use some indicators of complexity: pathology test volume and ED LOS, to investigate the strength of the relationship between the complexity of a patient's condition and the reimbursement paid to the ED.

METHODS

URG codes are allocated to ED patient presentations based on three characteristics of their stay: mode of separation, triage category and MDB.[73] Therefore, the study period for these analyses was determined by the period that MDB codes were recorded in the ED information system. At Hospital C, MDBs were recorded starting in July 2008, at Hospitals A, D, E and F, MDBs were recorded starting in July 2009. The analyses covered data from these starting dates until December 2013.

The mean number of pathology tests and the median ED LOS was calculated for all the presentations within each URG category. Only URGs associated with an MDB were included in the analyses, resulting in the exclusion of URGs where the patient was dead on arrival to the ED, died while in ED, was transferred to another facility, did not wait for treatment, or it was a planned returned visit.

A list of the reimbursement paid to EDs for each URG in NWAU(13) units was downloaded from Independent Hospital Pricing Authority website[74] and converted to AUD units using the NEP value for 2013-2014, of $4,993.[72]

The relationship between reimbursement and each measure of complexity was plotted separately. Pearson correlations were calculated to show the strength of the relationships. Each URG contributes a single data point to each figure; they are not weighted for the number of ED presentations.

URGs where the ED presentation resulted in hospital admission were plotted separately (blue diamonds) to URGs where treatment was completed in the ED (red squares).

RESULTS

Figure 22 shows that there was a positive correlation between the mean number of pathology tests and reimbursement in AUD units for ED presentations that did not result in a hospital admission (Pearson r =.76). There was also a weaker, but still positive, correlation for ED presentations that did result in a hospital admission (Pearson r =.53).

As was the case for the mean number of pathology tests, Figure 23 shows the relationship between the median ED LOS for each URG and the AUD value amount of reimbursement received from the Department of Health. There was a strong positive correlation between ED LOS and AUD reimbursement for patients who were not admitted (Pearson r =.76, the same correlation as for pathology tests), but the correlation was negative for patients who were admitted as hospital inpatients (Pearson r =-.33).

Appendix B provides additional detail of patient characteristics (such as median patient age, proportion of female patients) and the ED presentation (such as the proportion of ED patients who presented to one of the study EDs within 28 days of being discharged).

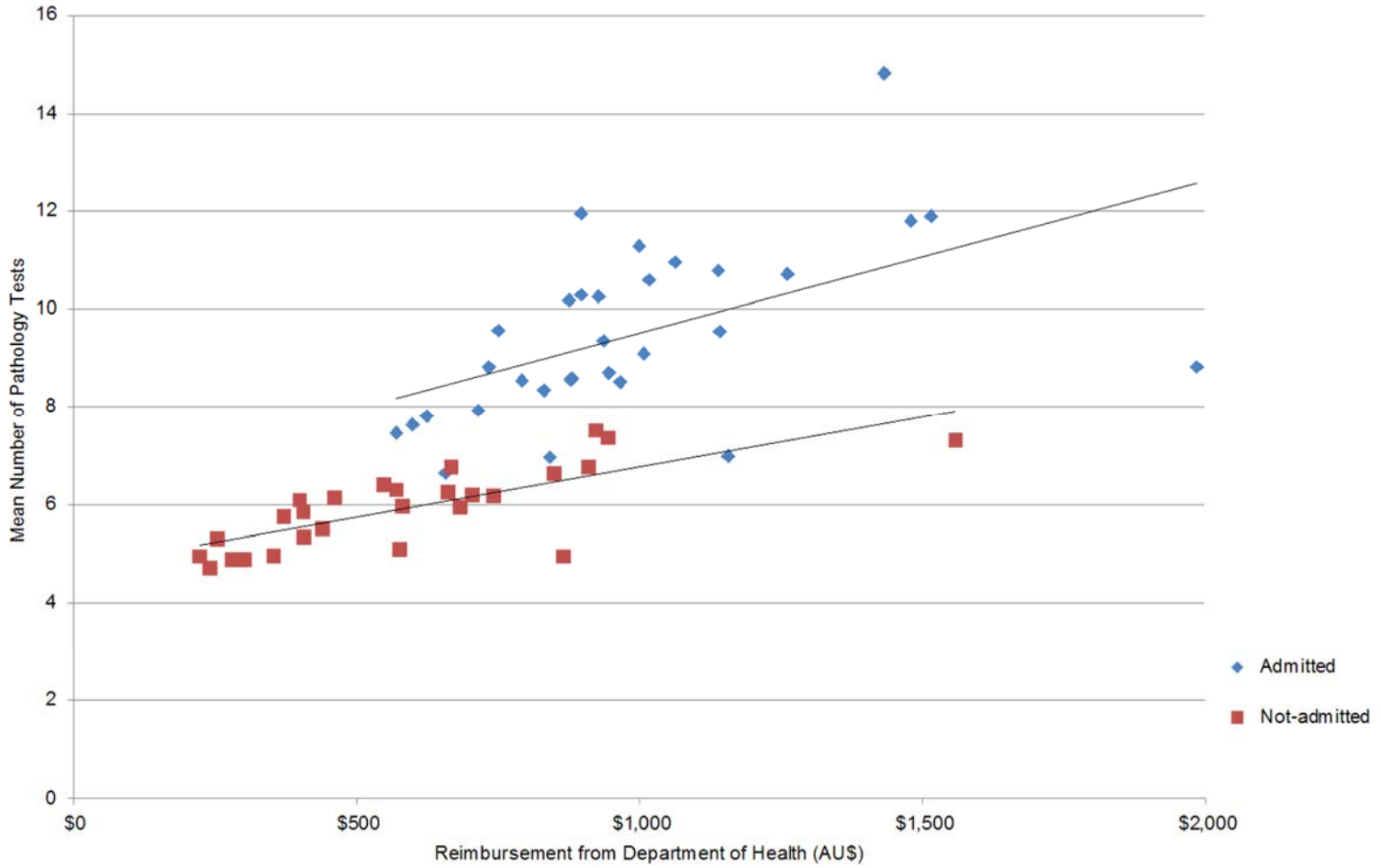

Figure 22. A comparison between URG codes resulting, and not resulting, in an inpatient admission, of the mean number of pathology tests for each ED presentation and the Reimbursement from the Department of Health (in AUD). Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

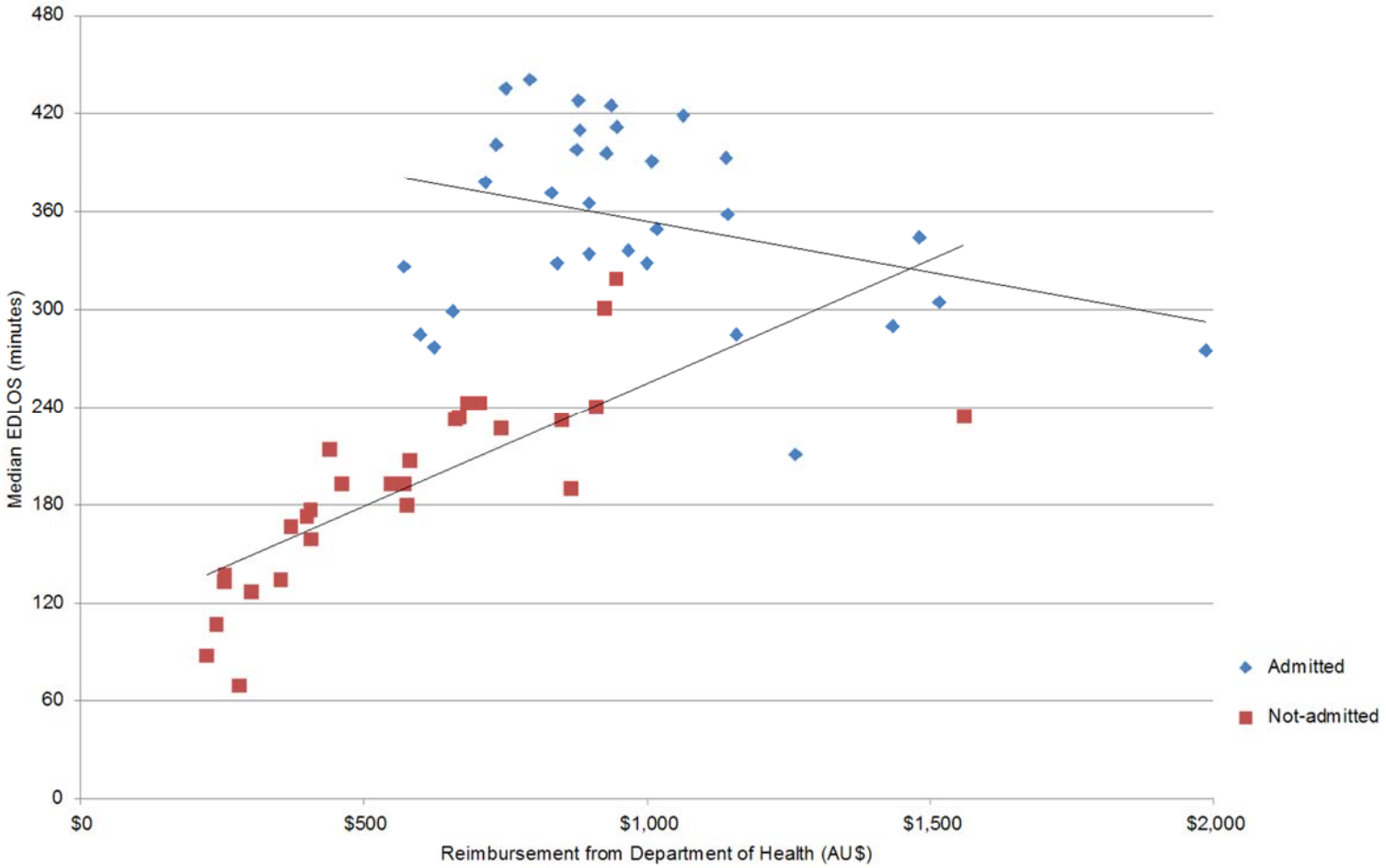

Figure 23. A comparison between URG codes resulting, and not resulting, in an inpatient admission, of the median Length of Stay of each ED presentation and the Reimbursement from the Department of Health (in AUD). Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

SECTION XV: DISCUSSION AND IMPLICATIONS

This project built on a funded QUPP project entitled 'The impact of the implementation of electronic ordering on hospital pathology services'.[1] The present project drew together different health information data sources to investigate the use of DRGs as a monitoring tool of pathology test utilisation and its impact on patient outcome measures including length of stay.

Quality improvements in pathology requesting are dependent on the availability of quality data about current practices in order to identify areas for improvement in the quality use of pathology. Quality data should provide the basis for meaningful comparisons between different locations, across different points in time. Casemix control is required to reduce the likelihood that any differences that are discovered are due to patient characteristics rather than differences in clinical and laboratory practices. DRGs in the inpatient context (and MDBs and URGs for ED patients) provide a basis to compare profiles of pathology requesting for similar patient groups across hospitals, between clinicians and at different points in time.

This project began with a literature review that assessed how DRGs (and other casemix coding systems) have been used in the assessment and evaluation of pathology laboratory testing. The literature review revealed four main classes of outcome measures: Appropriateness of test selection, Cost-control, Patient outcomes and Utilisation. A selection of these outcome measures were used in the project to assess the variation in pathology test utilisation practices between hospitals and across time.

The aim of this project was to undertake an extensive data linkage exercise using data from the pathology service along with key hospital data sources to examine the DRG profile of pathology requesting, along with their impact on hospitals costs and their effect on key clinical outcomes (e.g. length of stay). We conducted multiple data linkages across from six different sources: the LIS, the PAS, the ED information system, two different components of the EMR (Caresets and Locations datasets) and Hospital A's Medical Imaging department's RIS (Imaging dataset).

A comparative (across hospital and clinician level) analyses was performed covering six hospitals (including metropolitan and regional hospitals) in two Local Health Districts and a Children's Hospitals Network. This included comparisons of the mean overall pathology test utilisation per patient day in each hospital, using Poisson modelling that adjusted for casemix and patient characteristics. Comparisons showing distributions of pathology utilisation for specific DRGs (A06B: 'Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC'; and F74Z: 'Chest Pain') were also carried out across hospitals. In addition to comparing the number of tests ordered for each patient presentation, variation in clinician practices in pathology test utilisation for patients admitted as inpatients with the 'Chest Pain' DRG (F74Z) were reported, where the unit of comparison was clinicians rather than patient presentations.

Another project goal was the development of statistical and economic modelling to establish the relationship

between pathology requesting profiles and patient outcomes (e.g. length of stay in hospital, phlebotomy episodes, rates of hospital re-admission) and resource utilisation. This section focused on the ED context and used GEE multilevel modelling techniques to investigate the association between pathology testing and imaging procedures and changes in the duration of the ED presentation (ED LOS). The strength of the relationship between pathology test utilisation in the ED (as a proxy of the complexity of patient illness) and the amount of money paid (in AUD) to the hospital for that ED presentation according to the URG classification that had been made was also assessed. For each URG, the proportion of patients who presented to *any* of the study EDs within 28 days of leaving the ED were calculated (see Appendix B).

The project aimed to create benchmark utilisation tables against which other hospitals can compare their own performance while using DRGs to account for patient casemix and other potentially confounding variables. To enable this, tables of the Top-10 DRGs accounting for the highest pathology utilisation for inpatients, and the Top-10 MDBs accounting for the highest pathology test utilisation in the ED, were created and the actual test utilisation and median length of stay are reported. A detailed description of when repeat EUC and FBC tests were ordered relative to the preceding tests are provided for all patients and for specific DRGs.

LIMITATIONS

This is a comprehensive overview and comparison of pathology testing using DRGs, MDBs and URGs. As such it provides valuable information that can assist performance monitoring and inform future studies. However, there are some limitations to consider:

- The results are primarily descriptive. They generate questions for future collaborative research in the areas of appropriateness of test selection and repeat testing.
- The modelling of ED LOS revealed associations between pathology and imaging testing and ED LOS, but no causal inferences can be made from these results.
- The description of proportions of ED patients who presented again within 28 days only captured presentations that occurred at one of the five study EDs; repeat presentations at a non-study ED were not captured.
- The analyses of test selection in the ED was designed to investigate whether pathology test selection varied depending on the patient's presenting problem. Information about presenting problem is recorded as free text in the ED information system at the beginning of an ED presentation. However, a high level of variability in syntax and detail for these records was found. For this reason the MDB code (consisting of 27 discrete categories), which is entered into the ED information system at the completion of an ED presentation, was used as a substitute.

CONCLUSION

The outcome of this project was to produce a detailed analysis of hospital performance that assesses pathology test utilisation volume and rates per patient admission, per patient day and per clinician, that also incorporates measures of economic performance, cost effectiveness and the impact on patient care.

This resource has the potential to benefit a range of different stakeholders in the healthcare system.

PATIENTS/CONSUMERS

The benchmark measures can assist in improving the standardisation of clinicians' test requesting practices. The resource also included patient-centric indicators which measured the quality of care (the rates and timing characteristics of repeat testing, the length of stay in the hospital or ED and the rates at which patients presented to a study ED within 28 days of the previous ED presentation).

CLINICIANS

Pathology services contribute to all branches of medicine. They assist the clinical decision making process and make a critical contribution to the well-being of patients. By profiling pathology utilisation via DRG codes and other patient characteristics, it was possible to control for patient casemix and other confounding variables and compare test selection and utilisation practices in different contexts and according to their impact on outcomes such as LOS.

HOSPITAL PATHOLOGY LABORATORIES

Measuring, benchmarking and comparing the use of pathology laboratory services is a critical process in the monitoring and quality improvement that all organisations should pursue. Performance benchmarks can enhance quality of practice across different sites.

HOSPITAL MANAGEMENT

The analyses of pathology utilisation according to DRG codes enable improved description and comparison of clinician test selection practices and the evaluation of cost effectiveness. Hospitals can compare their own clinicians to those at other sites and use performance data to generate discussion, and inform decisions for quality improvement and decision support within their own organisation.

GOVERNMENT DEPARTMENTS OF HEALTH AND LHDS

Departments of Health and LHDs can use the benchmark results from this project in macro-level decision making. For example, some aspects of clinical decision support (such as the creation and availability of Caresets, or duplicate test order alert parameters in the EMR) may be most effective if applied broadly across entire jurisdictions in the health system. The repeat test timing characteristics and Careset utilisation analyses produced in this project can inform which clinical decision support mechanisms are most likely to yield improvements in pathology requesting, which may favourably impact on patient outcomes.

APPENDIX A: HOSPITAL BY YEAR COMPARISON OF TEST UTILISATION FOR TOP-10 DRGs

The mean number of pathology tests ordered for each patient admission, the mean duration (in minutes) of each patient admission and, in parentheses, the number of tests and the number of patient admissions for Top-10 DRG admission codes associated with the highest pathology test utilisation. For privacy and statistical reasons, detailed information is not shown for cells representing fewer than ten admissions.

Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours

DRG		Year	Hospital A	Hospital B	Hospital C	Hospital D	Hospital E	Hospital F
A06B	Tracheostomy W/ Vent >95 hours W/ or W/O Cat CC	2008	209.89 (19940/95) 728		187.61 (12007/64) 853	164.00 (3116/19) 546	240.87 (23846/99) 690	200.34 (14625/73) 730
		2009	204.97 (19677/96) 786	≤ 10 admissions	177.13 (12399/70) 782	≤ 10 admissions	217.69 (22422/103) 667	191.68 (18210/95) 706
		2010	174.19 (13064/75) 820		187.51 (13126/70) 941	163.94 (2787/17) 483	237.17 (26563/112) 727	194.58 (19069/98) 735
		2011	201.63 (15324/76) 1022		187.76 (11641/62) 952	168.44 (2695/16) 505	229.34 (25686/112) 665	193.70 (22469/116) 696
		2012	233.67 (20563/88) 1085		193.98 (12027/62) 751	155.39 (3574/23) 420	248.08 (31010/125) 721	191.77 (22821/119) 586
		2013	188.77 (16989/90) 1020	≤ 10 admissions	165.29 (10909/66) 629	153.00 (3213/21) 555	235.81 (33014/140) 775	192.79 (20628/107) 664

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
Z60A	Rehabilitation W/ Cat CC	2008	119.62 (26435/221) 1521	≤ 10 admissions	≤ 10 admissions	72.68 (3852/53) 1078	104.73 (24401/233) 1167	≤ 10 admissions
		2009	110.89 (26393/238) 1670		≤ 10 admissions	57.47 (4885/85) 952	121.07 (36564/302) 1192	≤ 10 admissions
		2010	127.99 (31997/250) 1791	≤ 10 admissions	≤ 10 admissions	70.08 (6237/89) 1102	110.66 (32312/292) 1196	≤ 10 admissions
		2011	127.56 (35334/277) 2098	≤ 10 admissions	≤ 10 admissions	79.69 (6853/86) 1065	127.00 (42290/333) 1100	≤ 10 admissions
		2012	119.93 (44735/373) 1584		≤ 10 admissions	58.40 (5256/90) 861	110.42 (34008/308) 1082	64.58 (8976/139) 414
		2013	93.06 (32291/347) 1326		≤ 10 admissions	43.08 (3188/74) 740	109.72 (29296/267) 1133	62.75 (21398/341) 418

							Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours	
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
A06A	Tracheostomy W/ Ventilation >95 hours W/ Cat CC	2008	419.25 (10062/24) 1348		≤ 10 admissions	≤ 10 admissions	442.42 (21236/48) 1323	414.33 (17402/42) 1599
		2009	442.06 (14146/32) 1719		≤ 10 admissions	≤ 10 admissions	408.33 (16333/40) 1255	341.18 (15353/45) 1530
		2010	352.55 (10929/31) 1721		≤ 10 admissions	≤ 10 admissions	329.82 (16161/49) 1131	405.51 (16626/41) 1697
		2011	376.21 (9029/24) 1381		≤ 10 admissions	≤ 10 admissions	313.45 (14732/47) 1218	357.19 (16788/47) 1763
		2012	396.00 (5148/13) 1743		478.58 (5743/12) 4850	≤ 10 admissions	431.91 (13821/32) 1501	425.92 (10222/24) 1892
		2013	412.06 (7005/17) 1442		≤ 10 admissions		401.72 (11650/29) 1349	354.00 (6372/18) 1601

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
L61Z	Haemodialysis	2008	4.21 (10052/2385) 6	≤ 10 admissions	4.09 (45/11) 6	5.49 (5947/1083) 10	3.74 (14358/3842) 7	6.72 (13361/1988) 7
		2009	4.90 (5137/1049) 6		5.07 (152/30) 6	4.55 (5306/1165) 10	3.93 (11530/2931) 7	5.38 (12134/2254) 7
		2010	4.37 (4107/940) 6		≤ 10 admissions	4.41 (4290/972) 7	4.44 (13883/3130) 7	5.40 (11941/2210) 8
		2011	4.67 (3981/852) 6		≤ 10 admissions	4.73 (4326/915) 6	4.27 (13538/3168) 7	5.68 (10932/1926) 8
		2012	4.54 (4194/924) 6		≤ 10 admissions	4.82 (3385/702) 6	4.48 (13564/3027) 7	6.15 (9326/1517) 8
		2013	5.27 (6245/1186) 6		4.71 (66/14) 6	4.80 (3335/695) 6	4.67 (13297/2850) 7	5.16 (7991/1550) 8

			Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours					
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
G02A	Major Small and Large Bowel Procs W/ Cat CC	2008	77.23 (4402/57) 678	59.60 (894/15) 392	≤ 10 admissions	85.67 (1799/21) 488	111.06 (9440/85) 555	84.05 (5211/62) 443
		2009	87.93 (3693/42) 875	56.25 (900/16) 490	≤ 10 admissions	79.57 (1671/21) 467	151.29 (14221/94) 622	84.61 (7023/83) 559
		2010	65.52 (4062/62) 676	44.53 (668/15) 276	113.83 (1366/12) 1121	85.37 (2305/27) 564	140.01 (15681/112) 597	76.97 (5927/77) 501
		2011	107.92 (6475/60) 532	≤ 10 admissions	76.14 (1066/14) 452	85.71 (2657/31) 464	153.25 (20842/136) 579	72.58 (4282/59) 390
		2012	71.21 (5554/78) 453	≤ 10 admissions	≤ 10 admissions	70.94 (2483/35) 416	142.01 (20023/141) 560	81.61 (7753/95) 428
		2013	86.28 (5263/61) 567	≤ 10 admissions	130.07 (1951/15) 959	67.84 (3053/45) 422	136.70 (19274/141) 529	80.80 (8646/107) 436

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
F74Z	Chest Pain	2008	8.48 (6813/803) 26		10.25 (41/4) 16	8.97 (2089/233) 22	9.27 (8911/961) 34	8.59 (8007/932) 25
		2009	8.34 (7447/893) 28	≤ 10 admissions	≤ 10 admissions	9.09 (2109/232) 29	9.99 (8885/889) 34	10.24 (6259/611) 40
		2010	8.77 (6627/756) 29		≤ 10 admissions	8.72 (3862/443) 18	9.64 (8982/932) 34	10.09 (8241/817) 35
		2011	9.11 (6270/688) 30		≤ 10 admissions	7.55 (4530/600) 12	9.69 (9381/968) 35	8.12 (8787/1082) 22
		2012	8.66 (6355/734) 27		≤ 10 admissions	7.30 (5218/715) 10	8.57 (9391/1096) 29	8.13 (9118/1122) 19
		2013	7.94 (6666/840) 23		≤ 10 admissions	6.83 (3130/458) 11	7.53 (8438/1121) 25	8.50 (8538/1005) 20

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
E62A	Respiratory Infections/Inflammations W/ Cat CC	2008	37.59 (7443/198) 254		≤ 10 admissions	52.55 (1524/29) 235	41.35 (9014/218) 259	54.52 (5125/94) 351
		2009	38.32 (7012/183) 245	≤ 10 admissions	≤ 10 admissions	33.81 (1589/47) 167	42.00 (8443/201) 262	44.01 (4929/112) 271
		2010	39.70 (7067/178) 287	≤ 10 admissions	38.45 (423/11) 222	35.76 (1609/45) 208	41.04 (8290/202) 277	44.12 (4633/105) 299
		2011	40.35 (7425/184) 286	≤ 10 admissions	46.00 (644/14) 262	32.89 (1776/54) 216	42.28 (10655/252) 265	49.12 (7417/151) 339
		2012	39.15 (9866/252) 232		≤ 10 admissions	34.16 (2938/86) 191	36.81 (10453/284) 249	44.36 (11533/260) 284
		2013	31.77 (5052/159) 219		36.57 (256/7) 186	28.87 (2454/85) 223	31.26 (8565/274) 250	37.73 (11545/306) 228

			Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours					
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
T60A	Septicaemia W/ Cat CC	2008	59.74 (4839/81) 285		48.76 (3023/62) 221	48.39 (871/18) 275	62.56 (6694/107) 303	62.38 (3743/60) 382
		2009	54.72 (5308/97) 301	≤ 10 admissions	44.36 (3105/70) 214	43.15 (1122/26) 263	57.99 (6089/105) 326	65.86 (5730/87) 358
		2010	54.29 (5266/97) 333	≤ 10 admissions	49.15 (3883/79) 218	48.54 (1796/37) 213	62.06 (7696/124) 274	65.45 (4647/71) 353
		2011	60.82 (5535/91) 360	≤ 10 admissions	74.23 (1633/22) 288	46.44 (2833/61) 237	68.88 (7095/103) 358	66.02 (6932/105) 350
		2012	62.97 (6297/100) 355		≤ 10 admissions	44.36 (2484/56) 225	58.78 (9464/161) 319	68.14 (11515/169) 336
		2013	45.74 (6998/153) 306	≤ 10 admissions	104.00 (1456/14) 393	39.42 (2720/69) 241	54.20 (8726/161) 301	48.39 (13744/284) 266

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
Z60B	Rehabilitation W/O Cat CC	2008	46.51 (7069/152) 1345		≤ 10 admissions	35.48 (2874/81) 577	57.82 (9945/172) 727	
		2009	47.71 (9018/189) 1465		≤ 10 admissions	45.00 (3330/74) 597	54.83 (9211/168) 652	≤ 10 admissions
		2010	77.35 (13768/178) 1660			38.37 (2724/71) 629	43.25 (7049/163) 591	≤ 10 admissions
		2011	70.74 (11672/165) 2160		≤ 10 admissions	37.20 (2418/65) 676	47.79 (8220/172) 566	≤ 10 admissions
		2012	59.10 (13179/223) 1523	≤ 10 admissions	≤ 10 admissions	35.74 (2466/69) 622	43.78 (6918/158) 633	30.56 (4309/141) 233
		2013	47.08 (10123/215) 1310		≤ 10 admissions	32.08 (1989/62) 540	46.86 (5530/118) 687	27.90 (10882/390) 246

								Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG		**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
E65B	Chronic Obstructive Airways Disease W/O Cat CC	2008	14.87 (4878/328) 128		≤ 10 admissions	17.04 (3664/215) 121	17.23 (6239/362) 141	19.59 (6799/347) 132
		2009	15.07 (4672/310) 128		≤ 10 admissions	18.80 (3684/196) 138	17.12 (5667/331) 133	18.90 (7787/412) 121
		2010	16.45 (4541/276) 123		≤ 10 admissions	14.93 (3150/211) 112	17.35 (5501/317) 125	16.99 (7390/435) 113
		2011	15.37 (4410/287) 118		≤ 10 admissions	14.52 (3849/265) 103	19.56 (6182/316) 133	16.62 (6863/413) 117
		2012	16.16 (3943/244) 112		≤ 10 admissions	14.64 (3997/273) 95	17.51 (6112/349) 126	17.99 (6241/347) 109
		2013	13.61 (3594/264) 92		≤ 10 admissions	12.63 (3132/248) 103	12.98 (4853/374) 118	13.41 (2951/220) 82

							Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG	**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
Overall (All DRGs)	2008	20.89 (479340/22944) 180	7.40 (49209/6649) 133	19.05 (138934/7292) 118	14.72 (150626/10233) 102	21.43 (623129/29072) 143	19.21 (488779/25445) 133
	2009	22.38 (510675/22823) 204	8.41 (55814/6640) 137	18.96 (147382/7774) 120	14.58 (155768/10686) 101	22.09 (651356/29491) 145	20.10 (494535/24605) 153
	2010	22.53 (499268/22164) 209	8.71 (55132/6332) 134	18.46 (145922/7904) 117	14.04 (154582/11013) 97	22.63 (702624/31053) 145	18.26 (497151/27232) 138
	2011	23.59 (526335/22308) 208	8.67 (57598/6647) 132	18.12 (149257/8235) 113	13.42 (165739/12349) 89	23.40 (756980/32353) 145	18.61 (546765/29382) 134
	2012	23.72 (536097/22603) 202	9.04 (60041/6640) 135	19.54 (164993/8442) 109	13.05 (170702/13079) 82	22.53 (760133/33744) 143	19.14 (579505/30274) 130
	2013	20.37 (501311/24613) 171	8.60 (58803/6841) 131	20.25 (176066/8693) 110	12.63 (146304/11587) 90	20.12 (684948/34043) 138	18.70 (582971/31173) 127

							Mean No. of Tests Per Admission (No. of Tests/No. of Admissions) Mean Length of Stay in hours
DRG	**Year**	**Hospital A**	**Hospital B**	**Hospital C**	**Hospital D**	**Hospital E**	**Hospital F**
Overall (Top-10 DRGs)	2008	23.47 (101933/4344) 192	53.06 (902/17) 699	111.57 (19078/171) 647	15.22 (26718/1756) 103	21.88 (134084/6127) 126	20.64 (74276/3599) 80
	2009	32.76 (102503/3129) 315	49.00 (1078/22) 399	90.95 (18189/200) 644	14.11 (26180/1856) 108	26.99 (139365/5164) 160	20.93 (77555/3706) 92
	2010	35.68 (101428/2843) 367	37.47 (712/19) 454	106.80 (20933/196) 750	15.21 (29104/1914) 116	26.16 (142118/5433) 153	20.49 (79098/3860) 87
	2011	39.00 (105455/2704) 453	≤ 10 admissions	122.62 (17290/141) 899	16.24 (34069/2098) 110	28.29 (158621/5607) 156	21.90 (85636/3910) 94
	2012	39.56 (119834/3029) 406	≤ 10 admissions	173.27 (19233/111) 1088	15.85 (32536/2053) 105	27.24 (154764/5681) 153	25.89 (101814/3933) 114
	2013	30.08 (100226/3332) 307	61.64 (678/11) 437	140.29 (20623/147) 828	14.92 (26214/1757) 108	26.05 (142643/5475) 149	26.04 (112695/4328) 134

APPENDIX B: PATIENT AND TESTING CHARACTERISTICS FOR URGENCY-RELATED GROUPS (URGs)

The relationship between each URG group and the Mode of Separation, Triage categories and Major Diagnostic Block (MDB) (the three factors used to allocate the URG), and the reimbursement received from the Department of Health (in both National Weighted Activity Units [NWAU13] and Australian Dollar [AUD] units using the 2013-2014 rate of AUD4,993 per NWAU13), patient age and sex, number of pathology tests ordered during the presentation, the number of imaging procedures ordered (data from 2013 calendar year only), the duration of the stay in ED and proportion of presentations followed by another presentation in ANY of the study EDs within 28 days. Study period was Jul 2009 to Dec 2013 at EDs A, D, E and F, and Jul 2008 to Dec 2013 at ED C.

U	a	b	c	d	e	f	g	h	i	j	k	l	m
03	Admitted	1	Injury	1100	0.3978 $1986	30 (15-52)	23.5%	8.8	8 (6-11)	0.1	329.8	275 (177-394)	7.3%
04	Admitted	1	Poisoning	283	0.2871 $1433	38 (29-51)	49.1%	14.8	14 (10-18)	0.2	438.4	290 (215-540)	11.3%
05	Admitted	1	Respiratory system illness	982	0.2965 $1480	69 (40-81)	45.9%	11.8	11 (8-14)	0.0	433.3	344 (227-528)	12.5%
06	Admitted	1	Circulatory system illness	1422	0.2528 $1262	70 (56-81)	37.5%	10.7	9 (7-12)	0.0	276.7	211 (109-347)	9.7%
07	Admitted	1	All other MDB groups	2312	0.3036 $1516	50 (20-74)	41.4%	11.9	10 (7-15)	0.1	382.3	305 (201-466)	9.0%
09	Admitted	2	Poisoning	925	0.2130 $1064	35 (21-48)	56.5%	11.0	10 (7-14)	0.1	550.2	419 (263-746)	16.9%
10	Admitted	2	Injury	4864	0.2319 $1158	30 (14-54)	30.3%	7.0	6 (5-8)	0.6	347.8	285 (192-425)	11.0%
11	Admitted	2	Gastrointestinal system illness	4784	0.2283 $1140	54 (31-73)	46.4%	10.8	9 (7-13)	0.2	460.7	393 (261-564)	14.8%
12	Admitted	2	Respiratory system illness	12603	0.2038 $1018	26 (2-74)	43.4%	10.6	10 (7-13)	0.1	425.2	349 (246-490)	14.4%
14	Admitted	2	Neurological illness	3940	0.2288 $1142	58 (31-78)	46.8%	9.5	8 (6-11)	0.3	435.7	358 (238-516)	12.6%
15	Admitted	2	Toxic effects of drugs	215	0.2020 $1009	36 (22-50)	38.6%	9.1	8 (6-11)	0.2	485.2	391 (261-640)	18.1%
16	Admitted	2	Circulatory system illness	22867	0.1936 $967	66 (52-78)	43.6%	8.5	8 (6-10)	0.2	408.3	336 (225-490)	13.8%
17	Admitted	2	All other MDB groups	10531	0.2003 $1000	44 (21-68)	43.4%	11.3	10 (6-15)	0.1	412.4	328 (220-491)	14.2%

U	a	b	c	d	e	f	g	h	i	j	k	l	m
19	Admitted	3	Blood/Immune system illness	5006	0.1798 $898	56 (13-76)	51.0%	11.9	10 (7-15)	0.1	413.9	334 (220-495)	22.7%
20	Admitted	3	Injury	14081	0.1686 $842	50 (17-80)	47.8%	7.0	6 (4-9)	0.5	406.3	328 (220-485)	11.2%
21	Admitted	3	Neurological illness	18713	0.1896 $947	65 (39-81)	53.3%	8.7	7 (5-10)	0.5	495.7	412 (278-602)	13.8%
22	Admitted	3	Obstetric/Gynaecological illness	2169	0.1143 $571	31 (25-38)	98.8%	7.5	6 (5-9)	0.1	381.2	326 (219-467)	17.7%
23	Admitted	3	Gastrointestinal system illness	32821	0.1876 $937	51 (26-73)	52.7%	9.4	8 (6-11)	0.2	498.7	425 (285-614)	15.4%
24	Admitted	3	Circulatory system illness	26067	0.1766 $882	72 (56-82)	48.3%	8.6	8 (6-10)	0.3	488.6	410 (278-590)	13.6%
25	Admitted	3	Poisoning/Toxic effects of drugs	2782	0.1760 $879	36 (21-51)	56.0%	8.6	8 (6-10)	0.2	522.6	428 (268-689)	20.2%
26	Admitted	3	Urological illness	9755	0.1860 $929	63 (41-79)	44.6%	10.3	9 (6-13)	0.2	469.2	396 (264-580)	19.2%
27	Admitted	3	Respiratory system illness	24403	0.1755 $876	57 (4-78)	46.2%	10.2	9 (7-13)	0.3	474.8	398 (279-568)	15.9%
29	Admitted	3	All other MDB groups	26150	0.1798 $898	41 (17-68)	46.9%	10.3	9 (6-13)	0.2	449.9	365 (239-549)	16.5%
30	Admitted	4	Poisoning/Toxic effects of drugs	1035	0.1432 $715	44 (26-57)	50.4%	7.9	7 (5-10)	0.1	454.2	378 (225-601)	23.6%
31	Admitted	4	Respiratory system illness	7150	0.1504 $751	54 (8-79)	48.1%	9.6	9 (6-12)	0.3	509.5	436 (291-630)	16.3%
32	Admitted	4	Gastrointestinal system illness	23979	0.1588 $793	45 (18-73)	55.4%	8.5	8 (6-10)	0.2	513.9	441 (289-642)	14.9%
33	Admitted	4	All other MDB groups	46339	0.1470 $734	64 (31-81)	54.3%	8.8	8 (5-11)	0.3	484.2	401 (261-598)	15.6%
34	Admitted	4	Injury	14066	0.1316 $657	41 (10-77)	48.3%	6.6	6 (4-8)	0.3	376.1	299 (194-466)	11.8%
35	Admitted	4	Psychiatric/Social problem/Other	6294	0.1666 $832	50 (30-76)	52.1%	8.3	7 (5-10)	0.1	451.9	371 (241-553)	18.5%

U	a	b	c	d	e	f	g	h	i	j	k	l	m
36	Admitted	5	Psychiatric/Social problem/Other	590	0.1201 $600	53 (31-76)	46.6%	7.6	7 (5-9)	0.0	354.1	285 (142-459)	19.7%
37	Admitted	5	All other MDB groups	4720	0.1250 $624	46 (21-72)	46.1%	7.8	7 (5-10)	0.1	351.6	277 (157-461)	14.9%
38	Dead on Arrival	any	any	1453	0.0316 $158	63 (48-77)	34.4%	-	-	-	33.7	18 (5-43)	-
39	Non-Admitted	1	All MDB groups	468	0.3123 $1559	24 (10-43)	39.1%	7.3	7 (5-9)	0.5	270.8	235 (164-323)	14.3%
40	Non-Admitted	2	Alcohol/drug abuse	167	0.1893 $945	35 (21-48)	34.1%	7.4	7 (5-9)	0.2	365.5	319 (206-474)	15.0%
42	Non-Admitted	2	Musculoskeletal/ connective tissue illness	327	0.1486 $742	42 (23-56)	39.8%	6.2	6 (5-7)	0.8	244.8	227 (168-308)	13.5%
43	Non-Admitted	2	Circulatory system/Respiratory system illness	8321	0.1824 $911	45 (14-63)	45.5%	6.8	6 (5-8)	0.8	270.6	240 (174-339)	15.0%
44	Non-Admitted	2	Injury	2577	0.1733 $865	22 (10-37)	28.9%	4.9	5 (3-6)	1.2	213.4	190 (126-266)	11.8%
45	Non-Admitted	2	Poisoning	253	0.1851 $924	27 (17-39)	50.6%	7.5	7 (5-9)	0.1	383.1	301 (176-503)	19.0%
46	Non-Admitted	2	All other MDB groups	6527	0.1702 $850	33 (17-52)	41.8%	6.6	6 (5-8)	0.6	260.6	232 (159-326)	16.4%
48	Non-Admitted	3	Circulatory system illness	19257	0.1412 $705	50 (33-68)	52.2%	6.2	6 (5-7)	0.6	274.3	243 (172-346)	12.1%
50	Non-Admitted	3	Injury	20763	0.1154 $576	23 (10-43)	38.0%	5.1	5 (3-6)	0.9	207.8	180 (118-261)	13.3%
51	Non-Admitted	3	Genitourinary illness	11303	0.1325 $662	34 (25-52)	61.9%	6.2	6 (4-8)	0.2	263.5	233 (163-328)	19.5%
52	Non-Admitted	3	Gastrointestinal system illness	21620	0.1337 $668	29 (8-50)	56.0%	6.8	6 (5-8)	0.3	264.3	234 (164-328)	17.4%
53	Non-Admitted	3	Neurological illness	14227	0.1368 $683	41 (21-62)	52.4%	6.0	5 (4-7)	0.6	275.8	243 (172-344)	15.4%
55	Non-Admitted	3	Respiratory system illness	25174	0.1143 $571	4 (1-27)	43.9%	6.3	6 (4-8)	0.7	216.2	193 (127-276)	17.0%

U	a	b	c	d	e	f	g	h	i	j	k	l	m
56	Non-Admitted	3	Musculoskeletal/ connective tissue illness	3370	0.1163 $581	41 (23-60)	51.4%	6.0	6 (4-7)	0.8	230.8	207 (139-290)	14.2%
57	Non-Admitted	3	All other MDB groups	32966	0.1098 $548	24 (4-45)	48.4%	6.4	6 (4-8)	0.2	222.9	193 (126-279)	18.4%
58	Non-Admitted	4	Injury	104609	0.0708 $354	17 (7-37)	41.5%	5.0	5 (3-6)	0.6	158.9	134 (83-207)	11.5%
60	Non-Admitted	4	Genitourinary illness	20018	0.0880 $439	31 (21-48)	73.0%	5.5	5 (3-7)	0.1	238.5	214 (142-305)	18.8%
61	Non-Admitted	4	Circulatory system/Respiratory system illness	51652	0.0815$ 407	7 (1-33)	48.5%	5.3	5 (3-7)	0.4	185.7	159 (99-240)	14.7%
62	Non-Admitted	4	Gastrointestinal system illness	53107	0.0922 $460	17 (4-37)	53.7%	6.1	6 (4-8)	0.1	220.2	193 (124-283)	15.9%
63	Non-Admitted	4	Musculoskeletal/ connective tissue illness	18749	0.0800 $399	31 (13-54)	47.6%	6.1	6 (4-7)	0.6	199.0	173 (108-259)	14.2%
65	Non-Admitted	4	Illness of the ENT	17260	0.0604 $302	9 (3-33)	45.2%	4.9	5 (3-6)	0.1	149.5	127 (75-198)	14.0%
66	Non-Admitted	4	Illness of the eyes	8792	0.0510 $255	28 (8-47)	35.6%	5.3	5 (3-7)	0.1	160.9	137 (84-212)	13.9%
67	Non-Admitted	4	Other presentation block	11342	0.0744 $371	29 (5-57)	47.9%	5.8	5 (4-7)	0.2	192.6	167 (98-254)	19.9%
68	Non-Admitted	4	All other MDB groups	76025	0.0813 $406	21 (3-45)	50.3%	5.8	5 (4-7)	0.2	204.9	177 (109-265)	18.1%
69	Non-Admitted	5	Poisoning/Toxic effects of drugs	832	0.0561 $280	32 (16-50)	37.0%	4.9	5 (3-6)	0.0	117.6	69 (27-166)	12.0%
70	Non-Admitted	5	Injury	25719	0.0481 $240	26 (15-45)	39.8%	4.7	5 (3-5)	0.4	130.7	107 (59-177)	13.5%
71	Non-Admitted	5	Other presentation block	5088	0.0446 $223	34 (15-56)	41.9%	4.9	4 (2-6)	0.0	118.7	87 (41-163)	22.4%
72	Non-Admitted	5	All other MDB groups	30081	0.0508 $254	31 (17-50)	47.2%	5.3	5 (3-7)	0.2	159.0	133 (73-215)	17.6%
73	Did Not Wait	any	n/a	62007	0.0321 $160	26 (11-43)	48.9%	5.3	4 (3-6)	0.0	113.6	78 (30-161)	18.6%

U	a	b	c	d	e	f	g	h	i	j	k	l	m
74	Transfer Presentn	any	n/a	4129	0.1960 $979	35 (23-57)	60.9%	7.5	7 (5-9)	0.3	277.3	250 (133-380)	19.0%
75	Died in ED	any	n/a	1045	0.2686 $1341	79 (64-86)	42.5%	9.7	9 (6-12)	0.2	354.8	279 (160-456)	-
76	Admitted	any	Return Visit Planned	4743	0.0893 $446	38 (11-66)	45.7%	8.1	7 (5-10)	0.1	323.1	252 (148-414)	10.4%
77	Non-Admitted	1, 2, 3	Return Visit Planned	480	0.0949 $474	27 (5-54)	49.2%	6.0	6 (4-8)	0.2	217.8	192 (109-286)	15.0%
78	Non-Admitted	4, 5	Return Visit Planned	13486	0.0401 $200	32 (18-54)	43.4%	4.5	4 (2-6)	0.1	107.1	75 (42-142)	30.5%

U	Urgency-related Group (URG)	h	Mean Number of Pathology Tests in Presentation
a	Mode of Separation	i	Median Number of Pathology Tests in Presentation (IQR)
b	Triage	j	Mean Number of Imaging Procedures in Presentation
c	Major Diagnostic Block	k	Mean Length of Stay in minutes
d	Number of Presentations	l	Median Length of Stay in minutes (IQR)
e	Reimbursement from Department of Health (NWAU13 and AUDs)	m	Proportion of patients presenting to ANY of the five study EDs within 28 days of leaving this ED
f	Median Patient Age (Inter-Quartile Range)		
g	Proportion of patients who were FEMALE		

REFERENCES

1. Georgiou A, Vecellio E, Toouli G, *et al. The impact of the implementation of electronic ordering on hospital pathology services, Report to Commonwealth of Australia, Department of Health and Ageing, Quality Use of Pathology Committee.* Sydney: Australian Institute of Health Innovation University of New South Wales;2012.
2. Bayram C, Britt H, Miller G, Valenti L. Evidence-practice gap in GP pathology test ordering: a comparison of BEACH pathology data and recommended testing. University of Sydney; 2009.
3. Fetter RB, Shin Y, Freeman JL, Averill RF, Thompson JD. Case mix definition by diagnosis-related groups. *Medical care.* 1980:i-53.
4. Palmer KS, Martin D, Guyatt G. Prelude to a Systematic Review of Activity-Based Funding of Hospitals: Potential Effects on Health Care System Cost, Quality, Access, Efficiency, and Equity. *Open Medicine.* 2013;7(4):94-97.
5. Busse R, Geissler A, Quentin W, Wiley M. *Diagnosis-Related Groups in Europe: Moving towards transparency, efficiency and quality in hospitals.* McGraw-Hill International; 2011.
6. Independent Hospital Pricing Authority (IHPA). Activity Based Funding. 2014. http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/funding. Accessed 28 October 2014.
7. Li L, Georgiou A, Vecellio E, *et al.* Impact of the performance of pathology service on patient length of stay in an emergency department using a multilevel regression model. Australasian Applied Statistics Conference (3–7 December); 2012; Queenstown, New Zealand.
8. National Coalition of Public Pathology. *Encouraging Quality Pathology Ordering in Australia's Public Hospitals.* National Coalition of Public Pathology; 2012.
9. van Walraven C, Raymond M. Population-based study of repeat laboratory testing. *Clinical Chemistry.* 2003;49(12):1997-2005.
10. Bates DW, Kuperman GJ, Rittenberg MA, *et al.* A randomized trial of a computer-based intervention to reduce utilization of redundant laboratory tests. *American Journal of Medicine.* 1999;106(2):144-150.
11. Kamal J, Rogers P, Saltz J, Mekhjian H. Information warehouse as a tool to analyze Computerized Physician Order Entry order set utilization: opportunities for improvement. *American Medical Informatics Association Symposium Proceedings.* 2003:336-340.
12. Gortmaker SL, Bickford AF, Mathewson HO, Dumbaugh K, Tirrell PC. A successful experiment to reduce unnecessary laboratory use in a community hospital. *Medical care.* Jun 1988;26(6):631-642.
13. Bunton JL, Gaede JT. A study of clinicians' responses to abnormal laboratory data as a function of diagnostic related group and test classification by College of American Pathologists criteria. *American Journal of Clinical Pathology.* 1992;97(6):818-826.
14. Long MJ, Chesney JD, Ament RP. The effect of PPS on hospital product and productivity. *Medical Care.* 1987;25(6):528-538.
15. Ferraro MJ. Effect of diagnosis-related groups on diagnostic methodology in the hospital laboratory. *Diagnostic Microbiology and Infectious Disease.* 1986;4(3 SUPPL.):135S-142S.
16. Aziz A, Healy DA, Wong M, Coffey JC, Grace PA, Walsh SR. Prospective cost analysis study of cases of right iliac fossa pain. *Irish Journal of Medical Science.* March 2012;181:S29.
17. Barenfanger J, Drake CA, Lawhorn J, Kopec C, Killiam R. Outcomes of improved anaerobic techniques in clinical microbiology. *Clinical Infectious Diseases.* 2002;35(SUPPL. 1):S78-S83.
18. Barie PS, Hydo LJ. Learning to not know: results of a program for ancillary cost reduction in surgical critical care. *Journal of Trauma-Injury Infection & Critical Care.* 1996;41(4):714-720.
19. Board N, Caplan G. Implications of decreasing surgical lengths of stay. *Australian Health Review.* 2000;23(2):62-76.
20. Brimhall BB, Dean T, Hunt EL, Siegrist RB, Reiquam W. Age and laboratory costs for hospitalized medical patients. *Archives of Pathology & Laboratory Medicine.* 2003;127(2):169-177.
21. Cristina S, Allevi A, Taioli E, Anzalone N, Nicolosi A, Polli E. Analysis of diagnostic procedure costs for cerebrovascular disease admission to a highly specialized hospital. *Italian Journal of Neurological Sciences.* Aug 1991;12(4):397-405.
22. Cutler TW, Palmieri J, Khalsa M, Stebbins M. Evaluation of the relationship between a chronic disease care management program and California pay-for-performance diabetes care cholesterol measures in one medical group. *Journal of Managed Care Pharmacy.* September 2007;13(7):578-588.
23. DesHarnais S, Kibe NM, Barbus S. Blue Cross and Blue Shield of Michigan hospital laboratory on-site review project. *Inquiry.* 1983;20(4):328-333.
24. Edwards RT, Lapsley HM. A comparison of pathology usage in three New South Wales public hospitals. *Australian clinical review/Australian Medical Association [and] the Australian Council on Hospital Standards.* 1993;13(4):165-173.
25. Haschke-Becher E, Totzke U, Afazel S, *et al.* Clinical decision rules for the use of liquor diagnostics in hospitalized neurology patients reduced costs without affecting clinical outcomes. *International Journal of Technology Assessment in Health Care.* April 2009;25(2):208-213.
26. Jha AK, Kuperman GJ, Rittenberg E, Bates DW. Gender and utilization of ancillary services. *Journal of General Internal Medicine.* 1998;13(7):476-481.

27. Kerr GD, Dunt D, Gordon IR. Effect of casemix funding on outcomes in patients admitted to hospital with suspected unstable angina. *Medical Journal of Australia*. 19 Jan 1998;168(2):57-60.
28. Khaliq AA, Huang CY, Ganti AK, Invie K, Smego RA, Jr. Comparison of resource utilization and clinical outcomes between teaching and nonteaching medical services. *Journal of Hospital Medicine (Online)*. 2007;2(3):150-157.
29. Litwin MS, Kahn KL, Reccius N. Why do sicker patients cost more? A charge-based analysis of patients undergoing prostatectomy. *Journal of Urology*. 1993;149(1):84-88.
30. Lopez-Castroman J, Blasco-Fontecilla H, Paz-Yepes M, *et al.* Cost-efficiency of laboratory testing among psychiatric inpatients. *International Journal of Psychiatry in Medicine*. 01 Jan 2012;44(3):211-224.
31. Steiner JW, Root JM, White DC. Laboratory cost and utilization containment. *Clinical Laboratory Management Review*. 1991;5(5):372-374, 376, 378-384.
32. Van Rhee J, Ritchie J, Eward AM. Resource use by physician assistant services versus teaching services. *Journal of the American Academy of Physician Assistants*. Jan 2002;15(1):33-38, 40, 42.
33. Wachtel T, Moulton AW, Pezzullo J, Hamolsky M. Inpatient management protocols to reduce health care costs. *Medical Decision Making*. 1986;6(2):101-109.
34. Wu AHB, Clive JM. Impact of CK-MB testing policies on hospital length of stay and laboratory costs for patients with myocardial infarction or chest pain. *Clinical Chemistry*. 1997;43(2):326-332.
35. Angle N, Dorafshar AH, Moore WS, *et al.* Open versus endovascular repair of abdominal aortic aneurysms: What does each really cost? *Annals of Vascular Surgery*. September 2004;18(5):612-618.
36. Broyles RW. Efficiency, costs, and quality: the New Jersey experience revisited. *Inquiry*. 1990;27(1):86-96.
37. Dorafshar AH, Reil TD, Moore WS, *et al.* Cost analysis of carotid endarterectomy: Is age a factor? *Annals of Vascular Surgery*. November 2004;18(6):729-735.
38. Petersen JR, Okorodudu AO, Mohammad AA, Fernando A, Shattuck KE. Association of transcutaneous bilirubin testing in hospital with decreased readmission rate for hyperbilirubinemia. *Clinical Chemistry*. March 2005;51(3):540-544.
39. Plapp FV, Essmyer CE, Byrd AB, Zucker ML. How to successfully influence laboratory test utilization. *Clinical Leadership & Management Review*. 2000;14(6):253-260.
40. Bowers JA. A cost benefit analysis of outsourced laboratory services. *Journal of Healthcare Resource Management*. Nov 1995;13(11):13-17.
41. Becker ER, Sloan FA. Utilization of hospital services: the roles of teaching, case mix, and reimbursement. *Inquiry*. 1983;20(3):248-257.
42. Davidoff F, Goodspeed R, Clive J. Changing test ordering behavior. A randomized controlled trial comparing probabilistic reasoning with cost-containment education. *Medical Care*. 1989;27(1):45-58.
43. Goldman ES, Easterling MJ, Sheiner LB. Improving the homogeneity of diagnosis-related groups (DRGs) by using clinical laboratory, demographic, and discharge data. *American Journal of Public Health*. 1989;79(4):441-444.
44. Mozes B, Easterling MJ, Sheiner LB, *et al.* Case-mix adjustment using objective measures of severity: The case for laboratory data. *Health Services Research*. 1994;28(6):689-712.
45. Racine AD, Stein RE, Belamarich PF, *et al.* Upstairs downstairs: vertical integration of a pediatric service. *Pediatrics*. 1998;102(1 Pt 1):91-97.
46. Sato D, Fushimi K. Impact of teaching intensity and academic status on medical resource utilization by teaching hospitals in Japan. *Health Policy*. 2012;108(1):86-92.
47. Sloan FA, Morrisey MA, Valvona J. Medicare prospective payment and the use of medical technologies in hospitals. *Medical Care*. 1988;26(9):837-853.
48. McMahon Jr LF, Hayward RA, Bernard AM, Rosevear JS, Weissfeld LA. APACHE-L: a new severity of illness adjuster for inpatient medical care. *Medical Care*. May 1992;30(5):445-452.
49. Zimmerman JE, Seneff MG, Sun X, Wagner DP, Knaus WA. Evaluating laboratory usage in the intensive care unit: patient and institutional characteristics that influence frequency of blood sampling. *Critical Care Medicine*. 1997;25(5):737-748.
50. Maor Y, Rubin HR, Gabbai U, Mozes B. The importance of laboratory data for comparing outcomes and detecting 'outlier' wards in the treatment of patients with pneumonia. *Journal of Health Services & Research Policy*. 1998;3(1):39-43.
51. Lipsitz DJ, Nagler HJ, Giannelli A. A physician incentive compensation program in a staff model HMO. *HMO Practice*. 1993;7(2):82-87.
52. Katz SJ, McMahon LF, Manning WG. Comparing the use of diagnostic tests in Canadian and US hospitals. *Medical Care*. Feb 1996;34(2):117-125.
53. South Eastern Sydney Illawarra NSW Health. Our people and their health. 2011. http://pandora.nla.gov.au/pan/84928/20080528-1126/www.sesiahs.health.nsw.gov.au/Publications/People_and_Health/Our_People_and_Their_Health.pdf. Accessed 5 November 2014.
54. Valenstein P. Managing physician use of laboratory tests. *Clinics in Laboratory Medicine*. Sep 1996;16(3):749-771.
55. Crolla LJ, Stiffler PW, Vacca S, McNear S. The Laboratory Manager: Role in Compliance, Organizational Structure, and Financial Management. In: Lewandrowski K, ed. *Clinical Chemistry* -

Laboratory Management and Clinical Correlations. Philadelphia: Lippincott Williams & Wilkins; 2002:51-63.
56. Elghetanyn MT, Okorodudu AO. Management of Test Utilization In: Lewandrowski K, ed. *Clinical Chemistry - Laboratory Management and Clinical Correlations* Philadephia: Lippincott Williams & Wilkins 2002:223-330.
57. Hindmarsh JT, Lyon AW. Strategies to promote rational clinical chemistry test utilization.[see comment]. *Clinical Biochemistry*. Aug 1996;29(4):291-299.
58. Kim JY, Kamis IK, Singh B, Batra S, Dixon RH, Dighe AS. Implementation of computerized add-on testing for hospitalized patients in a large academic medical center. *Clinical Chemistry and Laboratory Medicine*. 2011;49(5):845-850.
59. Bosomworth M, Wilcox M, Gill AB. Responsible Pathology Requesting. 2012; http://www.pathology.leedsth.nhs.uk/pathology/Departments/BloodSciences/MinimumReTestIntervals.aspx. Accessed 27 February 2014.
60. McKinney J, Pham L, Chen K-C, Swaminathan A. The appropriate pathology test study: optimising pathology blood test ordering in the hospital setting. *Medical Student Journal of Australia*. 2012;4(1):24-28.
61. Guidelines & Audit Implementation Network (GAIN). Guidelines on the use of the laboratory. 2008; http://www.gain-ni.org/images/Uploads/Guidelines/Lab_Guide.pdf. Accessed 27 March 2014.
62. Hawkins RC. Laboratory turnaround time. *Clinical Biochemist Reviews*. 2007;28:179-194.
63. Howanitz JH, Howanitz PJ. Laboratory results. Timeliness as a quality attribute and strategy. *American Journal of Clinical Pathology*. Sep 2001;116(3):311-315.
64. Georgiou A, Westbrook J. Computerised order entry systems and pathology services - a synthesis of the evidence. *Clinical Biochemist Reviews*. 2006;27(2):79-87.
65. McCarthy S. How to introduce and monitor a pathway for appropriate test ordering in the ED: S.T.O.P. and think! Sensible test ordering practice at Prince Of Wales ED Sydney, Australia (Powerpoint presentation).
66. Royal College of Pathologists Australasia (RCPA), Australasian College for Emergency Medicine. Guideline on Pathology Testing in the Emergency Department. 2013. http://www.rcpa.edu.au/Library/Publications/Joint-and-Third-Party-Guidelines/Guidelines/Guideline-on-Pathology-Testing-in-the-Emergency-De. Accessed 13 October 2014.
67. Lippi G. Biomarkers of myocardial ischemia in the emergency room: cardiospecific troponin and beyond. *European journal of internal medicine*. Mar 2013;24(2):97-99.
68. Sokal J, Thorlacius L, Tam J. Manitoba Troponin Guideline. 2011. http://dsmanitoba.ca/wp-content/uploads/2014/09/MBTroponinGuidelin.pdf. Accessed 13 October 2014.
69. Than M, Cullen L, Aldous S, *et al.* 2-Hour accelerated diagnostic protocol to assess patients with chest pain symptoms using contemporary troponins as the only biomarker: the ADAPT trial. *Journal of the American College of Cardiology*. Jun 5 2012;59(23):2091-2098.
70. Garg AX, Adhikari NK, McDonald H, *et al.* Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. Mar 9 2005;293(10):1223-1238.
71. Berlin A, Sorani M, Sim I. Characteristics of outpatient clinical decision support systems: a taxonomic description. *Medinfo*. 2004;11(Pt 1):578-581.
72. Independent Hospital Pricing Authority (IHPA). The NEP. 2013. http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/nep-determination-2013-14~02-nec-2013~2-1-nep. Accessed 13 October 2014.
73. Australian Institute of Health and Welfare (AIHW). Urgency related groups. 2013; http://meteor.aihw.gov.au/content/index.phtml/itemId/496744. Accessed 5 November 2014.
74. Independent Hospital Pricing Authority (IHPA). NEP determination 2013-14 Price weights - ED URG. 2013. http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/CA25794400122452CA257B1D0077899F/$File/2013-14%20NEP%20Price%20Weights%20-%20ED%20URG.pdf. Accessed 13 October 2014.

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