

Research Article

Clinical Application of Point-of-Care Testing in the Remote Primary Health Care Setting

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ABSTRACT

Background: Point-of-care testing (POCT) enables immediate pathology results to be used for timely clinical action during the patient presentation. While many benefits of POCT for chronic and infectious conditions have been well-documented, few studies have focussed on the clinical benefits of POCT for acutely ill patients in remote communities.

Aim: To determine the clinical effectiveness of POCT as a decision support tool for triaging acutely ill patients in remote Australia.

Methods: An audit examined three acute medical presentations (patients with acute chest pain, patients with acute exacerbation of renal failure due to a missed dialysis session(s) and patients with acute diarrhoea) at six remote health centres in the Northern Territory where POCT was routinely available. The main clinical outcome was the percentage (%) of patients with each acute presentation who did or did not require evacuation (as a result of POCT measurement).

Results: 200 patient cases met the selection criteria for the presentation types. Of 147 patients with chest pain, 126 patients were not evacuated due to on-site POCT for troponin I; from this latter group, 48 patients (38%) would have been evacuated if POCT was not available. Three of seven patients (43%) identified with non-STEMI through POCT would not have been evacuated if POCT was unavailable. Of 17 patients evacuated with acute renal disease, four (24%) had initial potassium results >6.5 mmol/L; all four received calcium gluconate/resonium medication and serial POCT with decreased potassium levels at evacuation. All 10 patients evacuated with acute diarrhoea received rehydration therapy prior to evacuation.

Conclusion: POCT enabled more informed triaging of acutely ill patients requiring evacuation to a tertiary hospital as well as ruling out the need for evacuation for patients who could remain in the community and be stabilised.

Keywords: Point-of-care testing; Acute care; Remote; Rural; Primary health care; Patient safety

How this fits in with quality in primary care?

What do we know?

Current literature indicates that point-of-care testing (POCT) is able to provide improved detection and management of patients with chronic and infectious disease. Little information is available on the clinical benefits of POCT when used for acute care, particularly in the remote health setting.

What does this paper add?

This study provides quantitative evidence and illustrative case studies which highlight the clinical benefits of being able to conduct POCT for acute medical conditions in remote primary care.

For Indigenous Australians, there are also cultural benefits of acute POCT through stabilising a patient's clinical condition on-site and thereby enabling them to remain in community.

Background

In Australia, general health status and life expectancy of people living in rural and remote areas is significantly lower than those in metropolitan or urban locations [1]. While there are many well-documented reasons for these disparities, geographical distance from the services and resources available in large metropolitan centres is a major factor [2]. For pathology services, most laboratories are generally located in large

metropolitan centres close to a tertiary hospital. People living in these centres can generally expect to receive their pathology results on the same day or for emergency care within the hour [3]. For those living in rural or remote locations, the wait time for pathology results can range anywhere from 24 hours to 2 weeks [4,5]. In the case of an emergency a common option is to evacuate the patient to the nearest hospital to have the pathology tests conducted to assist in determining the patient's diagnosis.

Point-of-care testing (POCT) provides a means of obtaining immediate pathology results at the time of the patient presentation [4]. Furthermore, modern POCT devices are usually simple to operate, even by non-laboratory trained staff, providing there are appropriate training and support mechanisms in place [6].

In the Northern Territory (NT) of Australia, a POCT network operates in 72 remotely located primary health care centres to provide immediate pathology results for both acute and chronic patient care [7,8]. The POCT device used in the program is the Abbott i-STAT (Abbott Point of Care, USA), which measures a range of pathology tests for emergency medical situations including electrolytes, urea, creatinine, cardiac troponin I, glucose, lactate, haemoglobin and blood gases. These tests can be performed on a venous sample of 100 μ L or less, with results available in less than 10 min.

The NT POCT Program has been found to be operationally effective with high satisfaction rates reported by key stakeholders as well as an increasing volume of testing; analytically sound with POCT results achieving the same standards as Australian laboratories; and is able to produce significant cost benefits through preventing unnecessary medical evacuations [7-10].

While many clinical benefits of POCT in acute care have been previously examined in studies conducted in urban environments [11-14], few studies have focussed on the clinical benefits to patients who live in remote communities. Here we describe the results of a study which investigated the clinical benefits of POCT for patients located in remote NT. This research was supported by a grant provided by the Emergency Medicine Foundation (Emergency Medicine Foundation Ltd.).

Aim

The project intended to determine the effectiveness of using POCT as a decision support tool for triaging acutely ill patients in rural and remote Australia by auditing the clinical outcomes of three common acute medical presentations at selected remote health centres in the NT where POCT is available on-site to provide immediate access to pathology results.

Methods

Ethics

Ethics approval for this project was obtained from the Human Ethics Committee of the Northern Territory Department of Health and Menzies School of Health Research (Application Number 2015-2469, approved September 2015).

Site selection

Six remote health centres in communities with varying population sizes and locations were selected in an attempt to eliminate any potential sources of bias. The health centres chosen comprised two large centres (servicing an Aboriginal population base of between 2000-3000 clients), two medium-sized centres (approximately 1000 clients) and two small centres (<500 clients). Two of the health centres were located in the Central Australian region and four were from the Top End of the Territory.

The participating remote health centres received ongoing training and competency assessment for i-STAT POCT and conducted monthly quality control testing for continued surveillance of analytical quality.

Clinical presentations included in the study

Three common acute clinical presentations were investigated in the study: 1) patients with a primary presentation of acute chest pain (specifically those with a normal ECG who had clinical symptoms of non-ST elevation myocardial infarction [non-STEMI]); 2) patients with end stage renal disease (ESRD) with a primary presentation of chronic renal failure due to a missed dialysis session(s); and 3) patients with a primary presentation of acute diarrhoea with evidence of dehydration.

These clinical conditions were selected as the focus for this study because each relies heavily on pathology results to rule in or rule out the need for a medical retrieval or to determine the course of *in situ* patient management or treatment. For each of these conditions, there is a defined 'standard care' clinical protocol (with associated laboratory-based pathology testing) available through the Central Australian Rural Practitioners Association (CARPA) Standard Treatment Manual, with the evidence for the protocol provided in the compendium CARPA Reference Manual [15-17]. An alternate clinical pathway for those health services that have access to POCT (termed the 'POCT pathway') was developed by the investigator team for the study (including the Senior Rural Medical Practitioner [RO]). Figures 1-3 summarise these two alternate clinical pathways for each of the three medical conditions.

Patients with acute chest pain (non-STEMI)

The detection of cardiac troponin is now an integral component of the differential diagnosis of acute coronary syndrome (ACS) [18-20]. Cardiac troponin I (cTnI) is measured by the i-STAT using 17 μ L of venous whole blood with results available in 10 min. Patients presenting at participating remote health centres with acute chest pain that were identified as having an ST elevation on ECG (ST elevation myocardial infarction or STEMI) are generally evacuated immediately from remote health centres and did not form part of this study. Thus, the focus of this study was patients presenting with acute chest pain without ST elevation on ECG (known as non-ST elevation myocardial infarction or non-STEMI). Patients were triaged according to the POCT decision pathway shown in Figure 1.

Patients with ESRD following a missed dialysis session

People living in remote NT have very high rates of kidney disease compared to urban Australians [21]. Patients requiring dialysis commonly present to their remote health centre feeling acutely unwell as a result of missing a scheduled dialysis appointment, often due to other cultural priorities [22,23]. The current clinical protocol for remote health centres recommends an initial check of vital signs and an ECG as per Figure 2. However, management differs thereafter in sites without and with access to POCT for potassium measurement, which can be measured using the i-STAT on 95 μ L of venous whole blood with results available

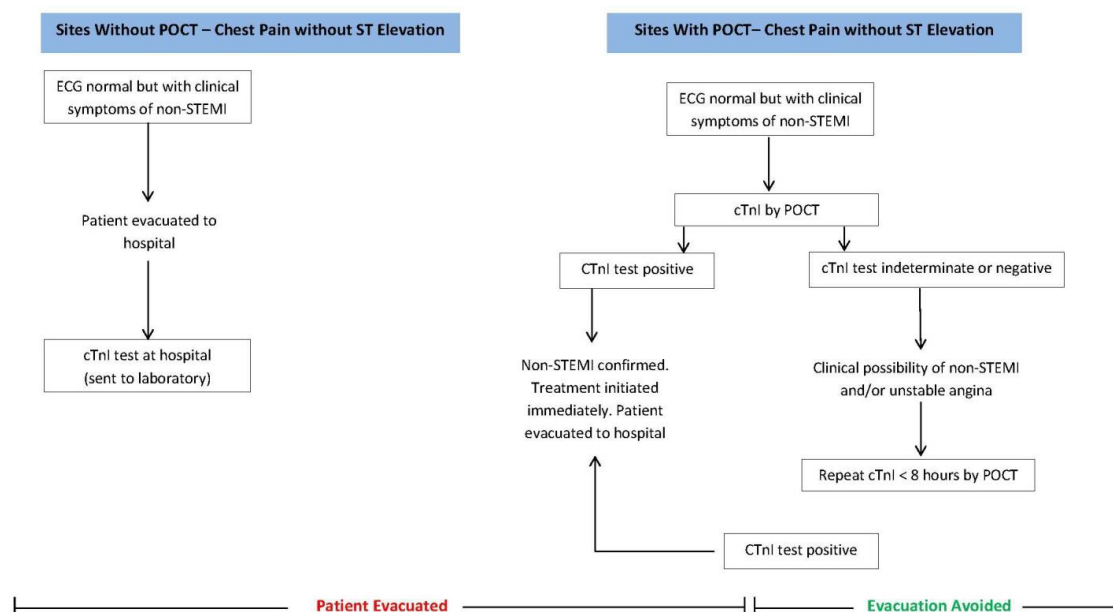


Figure 1: Clinical pathway for patients with acute chest pain (without ST elevation on ECG).

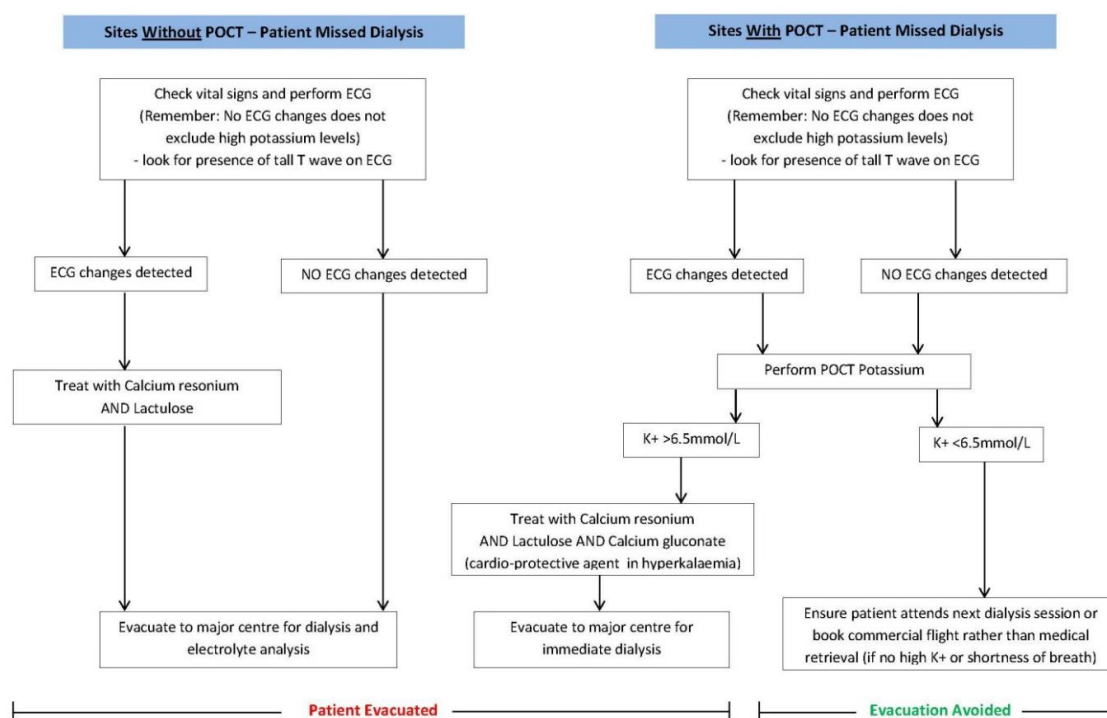


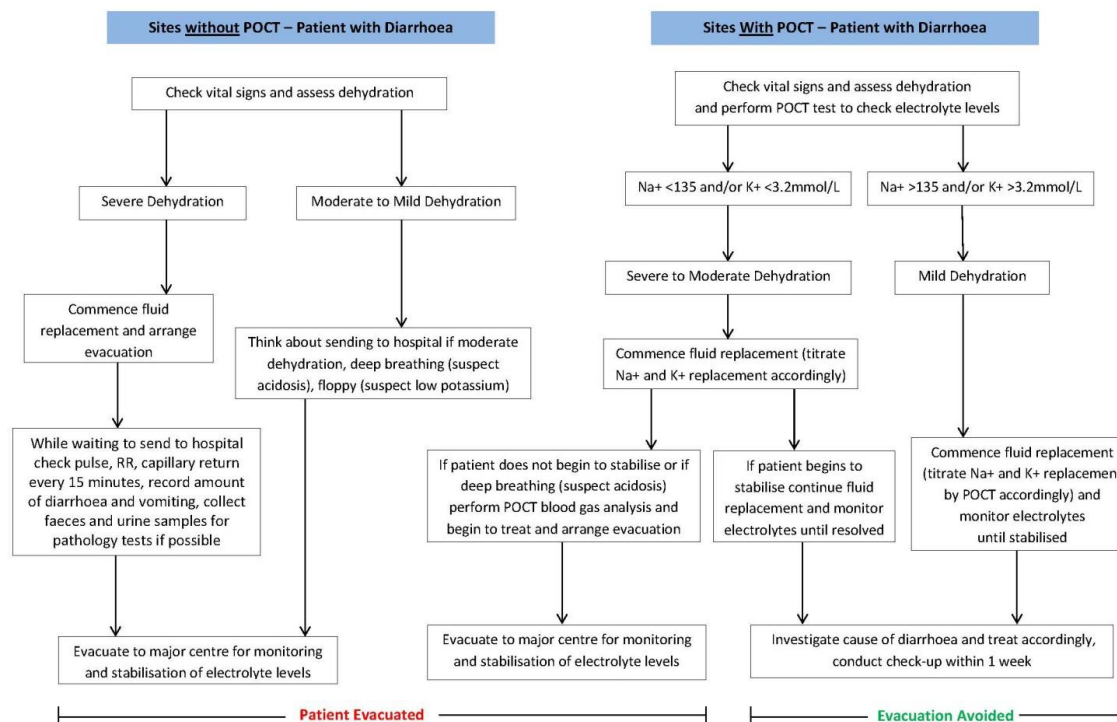
Figure 2: Clinical pathway for patients with ESRD and missed dialysis session(s).

in 2 min. A high potassium level (along with creatinine) is a key indicator of renal failure and the decision to evacuate the patient or not is highly dependent on the POC potassium result at a cut-off of 6.5 mmol/L [16].

Patients with acute diarrhoea

Acute diarrhoea is a particularly common acute medical condition observed in paediatric patients presenting to remote health centres in the NT [24]. It can be caused by a range of viral, bacterial or parasitic gastrointestinal pathogens and is often related to overcrowded living conditions and poor hygiene [25]. A major complication of acute diarrhoea is dehydration,

which is assessed by calculating the degree of water deficit/loss and treated by carefully managing the rehydration of the patient. Blood potassium and sodium are important biochemical markers for the assessment and management of diarrhoea and associated dehydration respectively. The i-STAT measures both sodium and potassium on 95 μ L of venous whole blood with results available in 2 min. The on-site turnaround of electrolytes by POCT potentially facilitates a more rapid and responsive rehydration of the patient [12]. Patients with acute diarrhoea (both adults and children) were triaged according to the POCT decision pathway shown in Figure 3.



POCT: Point-of-Care Testing, non-STEMI: Non ST Elevation Myocardial Infarction, cTnI: Cardiac Troponin I, ECG: Electrocardiogram, K^+ : Potassium by POCT, Na^+ : Sodium by POCT

Figure 3: Clinical pathway for patients with acute diarrhoea.

Data collection

The i-STAT Central Data Station (CDS), a centrally administered repository of all de-identified patient results captured electronically from each i-STAT device was used to search for POC test results from the six selected health services which fitted the above selection criteria shown in Figures 1-3 and across the 6 month data collection period.

POC test results initially sourced from the CDS ($n=417$) included:

- Any troponin I results (positive or negative) (to capture any potential case of Acute Chest Pain without ST elevation on ECG)
- Sodium [Na] results < 135 mmol/L and/or potassium [K] results < 3.2 mmol/L (to capture any potential case of Acute Diarrhoea with resultant dehydration)
- Creatinine > 200 μ mol/L (eGFR of approximately 35 ml/min/1.73m²) with a potassium result (of any concentration) also recorded (to capture any potential case of Chronic Renal Failure/missed dialysis session).

Clinical information on each patient who met one of the above 'test result' criteria was sourced from the Northern Territory's Department of Health Primary Care Information System (PCIS) to see if it could be included in (or excluded from) one of the three presentation types being investigated.

For each eligible patient case, the following demographic and clinical information was collected: Name of health service; patient identification number for each de-identified patient; age; sex; date of test; primary presentation; ECG result; medical

history; POC test result(s); initial diagnosis; evacuated (Yes/No); staff time required to prepare for and perform the test (min); time to diagnosis (min); time to initiate treatment (min); treatment/medication given at health centre; hospital diagnosis/outcome (if evacuated).

Outcome measures for clinical effectiveness

The main clinical outcome measured in this study was the percentage (%) of patients with each acute presentation type who did or did not require evacuation (as a result of POCT measurement). A clinical advisor [RO] provided an independent clinical judgement on whether each patient would or would not have been evacuated to hospital should the results from the i-STAT device not have been available at the time. The clinical advisor is a Senior Rural Medical Practitioner (RMP) with extensive experience in the decision making of patient evacuations. The clinical advisor also provides supervision and advice to other RMP staff in making the decision to evacuate patients.

The time to diagnosis (TTD) and/or time to treatment (TTT) [median \pm interquartile range, IQR [min/hour] was also documented for each presentation type.

A number of patient cases where the POC test results had produced a defined clinical benefit to the patient were also recorded.

Results

Patient demographics

A total of 200 patient cases (average age 47 years; 51%

males) met the selection criteria for the three presentation types. A summary of patient demographics based on each presentation type is provided in Table 1.

Patients presenting with chest pain - Evacuated

Seven patients were evacuated with positive cTnI results and had a diagnosis of non-STEMI confirmed. Three patients were evacuated on the basis of a single cTnI result and four were evacuated after serial measurements. All patients received the recommended thrombolytic drugs (Clopidogrel, enoxaparin and aspirin) prior to evacuation. Troponin results on all 7 patients are summarised in Table 2. The clinical advisor determined that three patients (43%) would NOT have been evacuated if the i-STAT device was unavailable and this likely would have resulted in a poorer outcome for the patient.

A case study describing one of the 7 patients who was

evacuated based on a positive troponin results is provided below.

Patient Case 1: A 54 year old male with a history of ischaemic heart disease (IHD), including a non-STEMI three years prior and coronary artery bypass graft (CABG) surgery in the previous year, presented to his remote health centre at 10 AM. The patient complained of an epigastric burning sensation for the past 6 hours which had been intermittent and worse when lying on his back. The patient had many other co-morbidities such as type 2 diabetes, dyslipidaemia and hypertension. On presentation the nurse noted the patient appeared bright and alert with no report of chest pain or any shortness of breath; he had been taking his regular medications as normal. The nurse's first impression was that the patient was experiencing reflux, and the patient was given 20 mL of Gastrogel; however this did not relieve the patient's burning sensation. The nurse then

Table 1: Characteristics of the 200 patients included in the study.

Patient Case Type	n	Male (%)	Median Age	Small A	Small B	Medium A	Medium B	Large A	Large B
Chest Pain Evacuated - cTnI positive	7	4 (57%)	56	0	1	0	2	1	3
Chest Pain Evacuated - cTnI negative	14	7 (50%)	47	1	3	3	3	1	3
Chest Pain NOT Evacuated- cTnI negative	126	68 (54%)	45	7	21	19	31	12	36
Missed Dialysis Session Evacuated	17	11 (65%)	53	0	1	9	1	1	6
Missed Dialysis Session NOT Evacuated	11	3 (27%)	53	1	0	4	4	0	1
Acute Diarrhoea Evacuated	10	4 (40%)	34 (7m-58y)	1	1	0	1	3	4
Acute Diarrhoea NOT Evacuated	15	5 (33%)	43	0	0	1	4	4	6
TOTAL CASES	200	102 (51%)	47years	10 (5%)	27 (14%)	36 (18%)	46 (23%)	22 (11%)	59 (30%)

Small A and Small B refer to the two small remote health centres participating in this study

Med A and Med B refer to the two medium-sized remote health centres participating in this study

Large A and Large B refer to the two large remote health centres participating in this study

Table 2: Serial troponin changes and time between troponin tests in patients who were evacuated and had non-STEMI confirmed.

Sex	Age	Primary Presentation	ECG 1	cTnI Result 1 (ng/mL)	cTnI Result 2 ng/mL (Δ time)	cTnI Result 3 ng/mL (Δ time)	Total time
39	F	Chest Pain	NAD	0.00	0.04 (1 h 45 min)	0.12 (1 h)	2 h 45 min
48	F	Non-STEMI	Abnormal	0.04	0.11 (2 h 30 min)		2 h 30 min
49	M	Chest Pain	NAD	0.04	0.33 (8 h 15 min)		8 h 15 min
69	M	Chest Pain	No changes	0.13	0.09 (4 h 15 min)	0.02 (8 h 15 min)	12 h 30 min
61	M	Myocardial Infarction	ST segment depression	0.94			
54	M	Cardiovascular Chest Pain	Inverted T waves	0.25			
74	F	Neck of femur fracture	ST segment depression	0.98			

Δ time: Time between serial troponin measurements

sought to rule out any cardiac involvement and performed an ECG and cTnI test on the i-STAT device. The cTnI result of 0.25 ng/mL (<0.08 ng/mL=negative) was reported over the phone to the on-call cardiologist. The ECG trace was faxed to the cardiologist who noted inverted T-waves in V2 of the trace and made a diagnosis of non-STEMI. The patient was administered the appropriate cardiac drugs (Aspirin 300 mg, Clopidogrel 300 mg and Clexane/Enoxaparin 80 mg injection) and transferred to the nearest tertiary hospital via emergency evacuation. The estimated time of arrival for the evacuation team was 4 hours after the initial request and, during this time, the patient remained stable with no chest pain but hypertensive (BP 153/95 mm Hg). Once the patient arrived at the hospital the decision to provide more extensive treatment was made and he was transferred to a different hospital with cardiac surgery facilities where he had

a stent inserted. After his surgery the patient was noted to be 'doing well' and had a video-link cardiology review scheduled every 6 weeks from his home community. Approximately 8 months later the patient experienced a chest pain episode that worried him and presented at his remote health centre clearly concerned. A negative cTnI test and normal ECG trace were recorded and the patient was treated with Gastrogel for reflux which reduced the pain dramatically. The patient had a follow up cTnI test and ECG trace performed the next morning as a precaution, with both tests being negative.

During the study period, an additional 14 patients were also evacuated with negative troponin results (13 had an initial cTnI of ≤ 0.02 ng/mL and one patient had an initial result of 0.07 ng/mL). Table 3 summarised the reasons for the evacuation of these patients with negative troponin results. Nine of the 14 patients

Table 3: Summary of patients with chest pain who had negative Troponin I result(s) but were evacuated for non-cardiac reasons.

Sex	Age	Primary Presentation	ECG 1	1 st cTnI Result (ng/mL)	2 nd cTnI Result (ng/mL)	3 rd cTnI Result (ng/mL)	Health Centre Reason for Evacuation	History	In-Hospital Diagnosis	Other Notes
F	47	Acute coronary syndrome	Normal	0.07			Treated as Acute Coronary Syndrome	Acute rheumatic fever	Influenza A	Stress test to be performed and angiogram ordered in hospital. Exact reason for evacuation unknown
F	28	Chest Pain	Normal	0.01			Review of general health requires evacuation to ASH	Dyslipidaemia, obesity, RHD, stage 1 RD, T2D	Angiography to investigate cardiac involvement showed no abnormalities	Evacuated for further investigation of chest pain
M	29	Chest Pain	No ST segment changes	0.00	0.00	0.00	Evacuate to ASH for further investigation as intermediate risk NTSEACS	Smoker, previous high BP, strong family history of HD	Atypical chest pain/constipation	Patient conveyed annoyance at normal troponin results as did not want to return to prison cell
F	71	Chest Pain	Abnormal (AF)	0.01			For RFDS transfer to ASH for further investigation of low K+	Reports previous heart attack, stroke, irregular HR, T2D	Exacerbation of Pulmonary Hypertension	Nurse stated overwhelmed with current patient load, RMP said to transfer to ASH ED
M	47	Chest Pain	Unchanged from previous	0.01	0.01		Cause of symptoms uncertain, only safe course of action is evacuate for assessment	Stage 3 CKD, T2D, IHD, asthma, dyslipidaemia	Cardiac ruled out with CT angiogram, likely musculoskeletal second to previous cervical spine injury	Pain eased. Documented cardiac symptoms, beware of aortic dissection, only safe action is to evacuate to ASH for cardiology monitoring and assessment
M	43	Chest Pain	T wave inversion V1-3	0.00			Cardiologist thinks patient is in heart block, not immediate cardiac concern but further investigations required	Hypertension	Pneumonia	Evacuation ordered before negative cTnI results obtained. Transfer for further investigation

F	54	Chest Pain	Normal	0.00		Evacuated due to atypical chest pain needing further investigation	Risk factors of IHD, mother had CABG, ex-smoker	Serial cTnI negative in hospital and formal Trop from RDH also negative.	Woke up with heavy chest pain, sweaty and nausea. Cardiac high risk patient
F	42	Chest pain and Fever	Normal	0.02		Fluid overload/renal failure	Dialysis, IHD, previous CABG, chronic CCF, T2D	CKD Stage 5	End of life issues discussed
F	45	Chest Pain and Headache	Normal	0.00		Cannot rule out Subarachnoid Haemorrhage therefore evacuated for further investigation	Diabetes	Left against medical care before investigations	Noted to be very odd presentation, patient very confused, cardiac ruled out but needs to be evacuated to RDH
M	62	Chest Pain, difficulty breathing	Arterial Fibrillation	0.00		Evac for investigation as similar episode 5 weeks ago	Triple bypass in 2000, stress test March 2015 with no major concern	AF with rapid ventricular response - to be managed with medication	On ambulance arrival patient was slumped on storage boxes in back of take-away shop
M	58	Chest Pain	Normal	0.02	0.03	URTI, fluid overload, evacuated 5 days later due to ongoing SOB and high creatinine	End stage renal failure, cardio high risk, COPD, smoking	Required urgent dialysis as severe metabolic acidosis, patient now on haemodialysis	Delayed evacuation and via low acuity transfer
F	35	Generalised Abdominal Pain	Normal	0.01		Evac for surgical assessment in RDH	Stage 1 Renal Disease	Acute abdomen/small bowel obstruction	Patient state unchanged with persistent abdominal pain, investigate for pelvic inflammatory disease/ARF
M	57	Radiating abdominal pain	Normal	0.02		RMP suggests further management in hospital as patient has some other ongoing issues	CCF secondary to RHD, x 3 valve replacement, IDH, chronic AF, stage 1 RD	Pain likely due to Urinary Tract Infection	Patient presented with radiating abdominal pain, even though no other symptoms transferred to hospital
M	42	Shortness of breath	Normal	0.01		Chronic Obstructive Pulmonary Disease	Cardiac high risk, heart failure in 2014, T2D, stage 1 RD, bronchiectasis in 2003	Infective exacerbation of bronchiectasis and type 2 respiratory failure	Difficulty breathing but no other abnormalities noted in case

CCF: Chronic Cardiac Failure; RD= Renal Disease; T2D: Type 2 diabetes; AF: Atrial Fibrillation; CABG: Coronary Artery Bypass Graft; COPD: Chronic Obstructive Pulmonary Disease; IHD: Ischaemic Heart Disease; ED: Emergency Department; RHD: Rheumatic Heart Disease; RMP: Rural Medical Practitioner; SOB: Shortness of Breath; URTI: Upper Respiratory Tract Infection; ARF: Acute Rheumatic Fever; ECG: Electrocardiogram; NTSEACS: Non-ST Elevation Acute Coronary Syndrome

were evacuated to have further investigations performed in hospital (outside of the remote health centres' capabilities). The clinical advisor noted that, of this group of 14 patients who had a negative troponin and were evacuated, all 14 would still have been evacuated if the i-STAT device was not available.

Patients presenting with chest pain – Not evacuated

Of the remaining 126 patients presenting with chest pain who were not evacuated, all had negative cTnI levels ≤ 0.04 ng/mL. Ninety seven (97) had a single cTnI result and 29 patients were ruled out after serial troponin measurements. The clinical advisor noted that, of this group of 126 patients not evacuated, 48 patients (38%) would have been evacuated if the i-STAT device was not available as cardiac involvement could not be ruled out without the cTnI POC test. Thirty one (31) of these 48 patients had a single cTnI test and 17 had serial cTnI testing to rule out cardiac involvement. All patients with negative troponin who were not evacuated had cTnI levels ≤ 0.04 ng/mL (that is; there were no patients with cTnI levels between 0.04-0.08 ng/mL who were not evacuated).

Patients with ESRD presenting after a missed dialysis session(s)

A total of 28 patients were identified as having chronic renal failure and having missed a dialysis session(s). The majority of patients in this group (n=20) came from two health services (one medium-sized and one large) who had a dialysis centre in the remote community. A summary of the data for the evacuated versus not evacuated group is summarised in Table 4.

Patients with ESRD presenting after a missed dialysis session(s) - Evacuated

Seventeen (60%) of patients were evacuated, all of which would still have been evacuated if the i-STAT results were unavailable. Four (24%) patients had an initial potassium >6.5 mmol/L; all of whom were treated on-site with calcium gluconate and/or calcium resonium. All four patients had further monitoring of their potassium levels prior to evacuation, with all reporting a decreased potassium level by the time the evacuation team arrived. One of the 4 patients had 7 serial potassium measurements (ranging from 7.6 to 4.1 mmol/L) over a 6 hour period before an evacuation was possible (with the evacuation delayed due to high demand for evacuations at the time). The remaining 13 (76%) patients evacuated had an initial potassium <6.5 mmol/L; however each of these patients had a confounding factor which necessitated their evacuation such as ECG changes, shortness of breath (SOB), fluid overload or sepsis.

Patients with ESRD presenting after a missed dialysis session(s) – Not Evacuated

Eleven (40%) patients did not require an evacuation; 10 (91%) of these evacuations were specifically prevented due to having the i-STAT results available. A case study describing one of the 11 patients who were not evacuated is provided below.

Patient Case 2: A 60 year old female of Indigenous descent presented to a remote health centre in the late afternoon having missed a dialysis session because she was visiting the remote community for a family funeral. The patient normally received dialysis in Darwin and wanted to know if there were any spare dialysis sessions in the community that she could attend to enable her to remain with her family for a few days. Upon presentation the nurse performed an ECG and measured electrolytes on the i-STAT tests. The ECG showed no abnormalities and the patient's potassium result was 5.5 mmol/L (reference interval 3.5-4.9 mmol/L). The nurse discussed the results with the on-site RMP who indicated the patient could not attend dialysis in the community as all the appointments were full; however, she was stable enough to remain in the community that day but needed to travel back to Darwin the next day for her normal dialysis session, to which the patient agreed.

The next afternoon the patient presented to the health centre again now feeling a little unwell and stating that she did not want to return to Darwin. The nurse performed a repeat ECG and electrolytes on the i-STAT. The ECG trace was normal; however the potassium result was slightly higher than the previous day (5.8 mmol/L). The RMP was called and he asked for further information regarding the patient. The patient was not short of breath, had no weakness, confusion, nausea or vomiting and reported no chest pain. The RMP indicated that the patient could remain in the community for one more night. To ensure the patient would return for dialysis the next morning PATS transport was arranged. The patient was transported back to Darwin the next morning and had dialysis performed at the hospital as she had missed her scheduled appointment.

Patients presenting with acute diarrhoea

A total of 25 patients were identified as presenting with acute diarrhoea (together with evidence of dehydration). Only 3 of 25 patients in this category were children, all of whom were evacuated.

Patients presenting with acute diarrhoea - Evacuated

Ten of the 25 patients identified were evacuated, with three classified as having severe dehydration and seven classified with mild to moderate dehydration. The reasons for patients

Table 4: Summary of evacuated versus not evacuated patients with ESRD presenting after a missed dialysis session(s).

Outcome	n	Average Dialysis sessions missed (n)	Initial potassium >6.5 mmol/L (n)	Mean K (mmol/L)	Initial creatinine >1768 μ mol/L (n)	Mean creatinine (μ mol/L)
Evacuated	17	2.5 (range 1-5) [n=16]	4	5.9 (\pm 1.1)	9	1172 (\pm 401)
Not Evacuated	11	1.7 (range 1-3) [n=6]	0	4.6 (\pm 1.0)	0	906 (\pm 380)

with mild to moderate dehydration being evacuated included further investigations for possible bacterial meningitis, acute gastroenteritis, acute renal failure, abdominal tenderness, pyrexia, and cerebrovascular incident.

All 10 patients received some form of rehydration therapy prior to evacuation. The clinical advisor indicated that 9 of the 10 patients evacuated would have still been evacuated without the i-STAT available. One patient was evacuated because they had evidence of renal failure (urea and creatinine elevated), which would not have been detected without the i-STAT device available.

Patients presenting with acute diarrhoea – Not evacuated

The remaining 15 patients presenting with acute diarrhoea remained in the health centre for monitoring and treatment, with all receiving some form of rehydration therapy during on-site stabilisation. The clinical advisor judged that two (13%) of the 15 patients would have required evacuation if the i-STAT was not available. One of these two patients was on haemodialysis at the time and the i-STAT enabled the patient's electrolyte results (including a potassium result of 4.9 mmol/L) to be monitored and an evacuation saved. In the second case, the i-STAT ruled out an evacuation of a patient with upper abdominal pain and diarrhoea. The electrolyte results allowed confirmation of safe treatment in the community for this patient who had a poor clinical history and uncertain diagnosis. A patient case is described below where the patient's electrolytes were titrated over three measurements and returned to normal, preventing an evacuation.

Patient Case 3: A 42 year old male with a history of chronic obstructive pulmonary disease (COPD) and IHD presented to his remote health centre with a three-day history of diarrhoea and coughing. The nurse assessed the patient as having generalised mild tenderness and signs of dehydration.

The on-call RMP then assessed the patient and confirmed his chest examination showed a probable chest infection. The RMP requested an ECG and asked the nurse to perform a cTnI, blood gas and electrolyte test on the i-STAT device. The ECG showed no major changes and the patient's blood gas and cTnI results showed no abnormalities; however, the electrolyte test revealed significantly low sodium and potassium levels of 129 mmol/L (reference interval: 138-149 mmol/L) and 2.9 mmol/L, respectively. The RMP advised the patient be administered IV antibiotics for the chest infection and normal saline and 600mg of slow release potassium chloride for rehydration and reassessment in the morning. The next day the patient had a follow up i-STAT test performed which showed that his electrolytes had improved (sodium 134 mmol/L, potassium 3.5 mmol/L). The patient did not return until one week later where he was administered further antibiotics for his chest infection and had a follow up tests indicating his electrolytes had returned to normal (sodium 138 mmol/L, potassium 3.9 mmol/L).

For each presentation type, no adverse events were recorded for patients not evacuated in the 10 days following their initial presentation.

Time to diagnosis and time to treatment

Table 5 summarises the TTD and TTT for patients presenting with each of the three acute presentations examined in this study.

The 'negative serial cTnI evacuated' group were diagnosed with other complications earlier and therefore had a shorter TTD, whereas the 'positive serial cTnI evacuated' group had to wait for repeat cTnI testing before a diagnosis could be made resulting in a longer TTD.

Of the patients who were not evacuated, only 26 of the 97 patients with a single cTnI tests and 11 of the 29 patients with serial negative cTnI results required treatment, with the median TTT of 15 min (± 20 min) and 30 min (± 45 min) respectively.

For the 28 patients presenting with chronic renal disease

Table 5: Time to diagnosis and time to treatment for evacuated and non-evacuated patients.

	n	TTD n (%)	Median TTD (IQR), min	TTT n (%)	Median TTT (IQR), min
Chest Pain					
Single Positive Evacuated	3	3 (100%)	20 (± 68)	3 (100%)	20 (± 5)
Single Negative Evacuated	11	11 (100%)	50 (± 130)	6 (55%)	38 (± 64)
Single Negative Not Evacuated	97	97 (11%)	30 (± 34)	26 (27%)	15 (± 20)
Serial Positive Evacuated	4	4 (100%)	255 (± 570)	4 (100%)	40 (± 20)
Serial Negative Evacuated	3	3 (100%)	100 (± 80)	2 (33%)	5 (± 0)
Serial Negative Not Evacuated	29	28 (97%)	480 (± 630)	11 (38%)	30 (± 45)
Missed Dialysis					
Evacuated	17	17 (100%)	108 (± 171)	14 (82%)	48 (± 43)
Not Evacuated	11	11 (100%)	150 (± 175)	3 (27%)	40 (± 3)
Acute Diarrhoea					
Evacuated	10	10 (100%)	44 (± 61)	10 (100%)	48 (± 66)
Not Evacuated	15	15 (100%)	45 (± 70)	11 (73%)	18 (± 5)

TTT: Time to Treat; TTD: Time to Diagnose; IQR: Interquartile Range

who missed a dialysis session, the median TTD was generally quicker for the evacuated group and the median TTT was similar for both groups.

Of the 15 patients who presented with acute diarrhoea/dehydration, the median TTD was similar for the evacuated and non-evacuated patient groups (approximately three quarters of an hour); however, four of the 15 patients not evacuated did not receive any treatment prior to discharge from the remote health centre. The time to treatment (TTT) was longer for the 'evacuated' group, which also had a very wide IQR.

Discussion

In terms of the clinical benefits to patients located in remote Australia, POCT was shown to provide significant improvements in patient care, including the more informed triaging of patients requiring evacuation to a tertiary hospital as well as ruling out the need for evacuation for patients who could remain in the remote community and be stabilised safely using the POCT device.

For patients presenting with chest pain (without evidence of ST-elevation of ECG) who were not evacuated, 38% (n=48) of this patient group would have been unnecessarily evacuated if the POC cTnI test was not available. These findings also demonstrate the cost benefits of POCT in preventing unnecessary medical evacuations which come at a high cost to the Northern Territory Government of \$136.30/min flight time according to its Fees and Charges Manual [26]. Importantly, patients with a single positive cTnI test received the fastest combined diagnosis and treatment times of any group (40 min total); however there was significant variability around results. The patient with chest pain (case one) demonstrates how initially POCT allowed for the quick diagnosis and early treatment of this acutely ill patient prior to evacuation and then later how POCT also enabled the quick rule-out of cardiac involvement for this concerned patient.

In the group of patients with ESRD who had missed a dialysis session(s), POCT enabled the rapid determination of patients who required urgent treatment based on their high potassium levels, which is not always possible using ECG alone. Furthermore, in this group of patients, POCT allowed for the close monitoring and stabilisation of patients' potassium levels until dialysis was possible, reducing their risk of a cardiac event caused by high potassium. Patient case two described how POCT was able to assist in the monitoring of a patient who had missed a dialysis session so she could attend a funeral in her home community and spend time with her family, demonstrating a cultural benefit of POCT. If the POCT device was not present in this case, the patient's potassium level could not be measured and she would have been evacuated to hospital for assessment of her electrolytes and renal function.

In terms of the patients presenting with acute diarrhoea and signs of dehydration, POCT was able to quantify each patient's level of electrolyte deficit and allow for the gradual and informed titration of electrolyte balance, which was evidenced by case three. In addition, patients with severe dehydration were quickly

identified and correctly evacuated for further management of their acute condition.

A limitation of this study is that only three common acute medical presentations were examined and the clinical application of POCT was not investigated for every patient presentation. In addition, the study did not investigate the effects of unnecessary medical evacuations on patient/community (e.g. loss of productivity or social or emotional wellbeing of Indigenous patients).

While the focus of this study was to examine the clinical effectiveness of POCT for acute presentations through the correct triage of acutely ill patients, POCT also enabled many patients to remain in their community, rather than having to suffer the social and emotional trauma associated with dislocation from their families by having to undergo an evacuation to a tertiary institution for further investigation.

In terms of cost effectiveness, the significant cost saving achieved by the NT POCT Program have been reported previously, with savings to the NT Government in excess of \$20 million per annum in prevented unnecessary medical retrievals [10].

The clinical benefits of POCT for managing remotely located patients with chronic illnesses have been long established [27-30]. This study provides for the first time a quantitative evidence base for the clinical effectiveness of POCT in an acute clinical setting, where previously only anecdotal evidence existed. The innovative use of POCT for acute medical presentations is now firmly embedded within the remote health care framework in the Northern Territory, one of the most challenging clinical environments for the delivery of health care. Clinical staff working in these remote, low resource locations now have access to quality assured POCT equipment for use as a tool to support clinical judgement and to enable better management of acutely ill patients.

Conclusion

POCT provides equity of access to pathology services for patients living in isolated locations, greater safety in acute care and timely clinical decision making. In these ways, POCT facilitates a closing of the gap in pathology service delivery that currently exists between regional/remote and urban settings.

This study provides health care policy makers with evidence that initial investment in POCT infrastructure and the appropriate quality framework, provides real improvements in acute care provision and patient safety in remote locations, with associated benefits of long-term cost savings.

This acute care POCT model has significant potential for translation to other disadvantaged settings and low-resource countries.

In terms of future directions, opportunities exist to explore other POC tests and test profile to support a broader range of clinical decisions across the acute, chronic and infectious disease spectrums.

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