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REVIEW

Review of Health Economics of Point-of-Care Testing Worldwide and Its Efficacy of Implementation in the Primary Health Care Setting in Remote Australia

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Abstract: There are important differences concerning health outcomes between the Australian population living in rural/remote regions and the urban population. Health care provision in remote areas, particularly in regions with a low number of inhabitants, is not without challenges. Aboriginal, rural and remote communities are therefore affected, as they face various obstacles in accessing health services, owing to geographical settings, difficulties in transportation to nearby hospitals, limited or inexistent local qualified personnel. The implementation of point-of-care testing could be a plausible solution to these challenges, as various point-of-care services that have been successfully put into action worldwide indicate towards positive clinical outcomes. Point-of-care units have a real potential in reducing morbidity and mortality in all population groups. This article aims to review the published literature on point-of-care testing around the world, with a focus on health economics and the feasibility of its implementation in Australian rural and remote regions.

Keywords: health economics, remote areas, point-of-care testing, cost-effectiveness

Introduction

In Australia, remote and rural areas encompass all regions outside major cities. Compared to the population living in urban regions, those from rural, remote and Aboriginal communities generally have higher levels of disease and injury, poorer health outcomes, limited accessibility to health services, and shorter life expectancy.[1] A range of factors may contribute to the aforementioned issues and they include disadvantages in education, employment, income and accessibility to health services.[1] Other responsible factors to be considered are higher physical risks in occupation, e.g. farming, mining, transportation, and higher percentage of adults engaging in unhealthy behaviours, such as tobacco smoking, alcohol abuse, poor diet and sedentary lifestyle.[1] Their health status is generally characterised by a higher prevalence of chronic and acute diseases, which often require urgent medical care and sometimes transferral with aerial medical services to the closest urban hospital.[2]

Therefore, implementation of point-of-care testing (POCT) or bedside testing in these remote areas could possibly be justified. Point-of-care testing covers diagnostic or laboratory testing performed via health care services provided near or at the patient's location (ISO 22870:2016). In the general practice, POCT may be undertaken in a variety of different locations such as home, pharmacy, sports clinic,

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workplace, ambulance, nursing home, general medical practice, rural and remote hospital or health clinic, hospital ward, clinic and/or critical care facility.[3]

This modern approach to health care, which is already implemented in various settings throughout the world, can lead to changes in patient care towards a more optimal outcome for the patient and more cost-effectiveness for the health system. Point-of-care testing is gaining importance in both developed and developing countries. In particular, POCT is an essential component of the medical system in those resource-limited locations where the health care, transportation, and infrastructure are suboptimal.[4] Furthermore, POCT allows for diagnostic evaluation without the reliance on laboratory infrastructure, averts the requirement for sample transport, and reduces processing times.[4] To serve its purpose, POCT involves relatively cheap, unpretentious, hand-held tools that do not entail broad training. All tests involved are completed close to the patient for a rapid result and can be easily implemented in remote settings that lack laboratory networks thus providing fast diagnosis and prompter treatment.[4,5]

Since prompt diagnosis and treatment are vital requirements to decrease morbidity and mortality, POCT has a real potential to reduce morbidity rates by enabling fast and efficient screening for varied diseases, leading to timely identification and management. The aim of this work was to collate the existing POCT studies reported on those health conditions that, according to the Australian government, are of major concern in rural and remote Australian regions (such as antenatal/neonatal care, cardiovascular disease).[1,51] The focus of the review is on health economics aspects, and the evaluation of cost-effectiveness to perform POCT in remote Australian regions.

Methods

A comprehensive literature search based on major databases (including Medline, Emcare, Embase and Scopus), a specific journal (Point of Care/The Journal of Near-Patient Testing & Technology) and pearling from selected articles was conducted. Database search was conducted with the following key terms: point of care testing, near-patient testing, physician office testing, off-site testing and alternative site testing; remote, rural, isolated, country, distant, Aboriginal and Indigenous; health economics, budget, efficient and finance; image, ultrasound and sonograph; and pregnant and antenatal. Search limits included English publications, human studies from 2000 onwards and studies published up to April 2020.

Four hundred and sixty-three abstracts were reviewed. Titles and abstracts were screened to remove publications that were apparently not relevant. Excluding the literature that was found to be extraneous, 61 articles have been identified as relevant. Case studies, conference abstracts, review and studies with small sample sizes were further excluded, while additional relevant articles through pearling and *Point of care* journal were added, with a total of 43 articles. A flowchart of search results is found in Appendix 1. The process of reviewing the identified studies was conducted independently by two authors, according to the inclusion and exclusion criteria. A list of potential papers was provided by each author. The two lists were compared and combined. In the case of a divergence between the two authors, the respective article was evaluated by a third author.

The inclusion criteria targeted studies based on all types of POCT for diseases of major concern in rural and remote Australian regions (such as antenatal/neonatal care, cardiovascular disease conditions), with a focus on health economics that evaluated either health or economic outcomes. Other papers were further removed based on the exclusion criteria, i.e. diseases outside major concern (e.g. sexually transmitted infections (STI)); studies that included only technology development; provided no or insufficient evidence for the cost or benefit of specific POCT; publications that are based on results from a survey and development for specific guideline; publications that are abstract, poster and protocol; and paper that are not human studies. Due to large variations in study design, targeted disease and population, and outcome reporting method of reviewed studies, statistical analysis of data has not been possible. As such, this is an integrative research review that summarizes current studies and evaluates the efficacy of implementation of POCT in the health care system, based on the reported health and economic outcomes of the POCT used for multiple health conditions in different regions. Data analysis based on selected literature is presented in Appendix 2; Figures A2.1–A2.5. This includes distributions of the final selected literature based on study type, cost analysis, disease type as well as studies classified as a function of the country's income level where point-of-care testing was evaluated. This work focuses on POCT studies reported on those health conditions that are of major concern in rural and remote Australian regions. These are related to antenatal/

neonatal care, cardiovascular disease and some general health conditions that comprise long-term respiratory disease, diabetes and chronic kidney disease.[1,51] The studies are summarised in a tabulated format in Appendix 3, based on the type of POCT (ultrasound, biomarker/lab test and models of care) for Tables A3.1 and A3.2, while Table A3.3 presents a compilation of the selected literature on POCT in general clinical diagnosis.

Results

Point-of-Care Testing Related to Maternal and Neonatal Care

Despite global progress and advances in health care, maternal mortality continues to be a great concern as according to international reports, an estimated 303 000 women and 2.87 million newborns die yearly.[6] Most maternal deaths (99%) occur in developing countries due to obstetric complications which are preventable or treatable with early diagnosis and access to appropriate intervention measures.[7] For instance, anaemia, infections, malaria and antepartum haemorrhage are treatable, while other complications (like pre-eclampsia and eclampsia) are manageable in antenatal care settings.[8]

Both maternal and neonatal care can greatly benefit from point-of-care ultrasound. Point-of-care ultrasound (POCUS) is not intended to be a substitute for a complex ultrasound practice but a targeted ultrasound test that can identify high-risk patients. For example, use of telecardiology showed that all foetuses with congenital heart disease (CHD) were correctly risk-stratified for delivery.[9] The cost of POCUS is a major economic aspect in developing countries as it is deemed suitable only if leading to similar outcomes but with lower expenses as compared to current obstetric examination.[10] Therefore, training and application of POCUS have to reflect the needs of the specific communities and must be tailored accordingly.[11] Table A3.1 is a compilation of POCUS studies and their findings regarding neonatal and maternal care.

In developing countries, antenatal ultrasound is usually available in urban areas only, despite the fact that most of the population resides in rural regions with limited or nonexistent access to these devices.[10] A successful approach that shows unfailing promise in decreasing maternal mortality ratio (MMR) is the presence of an experienced health care personnel at birth.[12] A study analysing the outcome of an antenatal ultrasound program implementation in a health care clinic in rural Uganda showed an increase of mean monthly deliveries by 17, whereas the monthly antenatal clinic visits increased by 97.4.[12] With increased deliveries and clinic visits, maternal and neonatal mortality and morbidity could be improved with early diagnosis and management.[11]

With technological advances, the cost of ultrasound machines has continuously decreased. Modern battery-based portable machines offer good-quality images at reduced costs with the added advantage of being user-friendly and chargeable using solar power.[13] Crispín-Milart et al investigated the impact of a newly employed project – the Innovative Healthy Pregnancy – that reinforces the local antenatal care program and provides local nurses with portable ultrasound equipment and afferent training. In the intervention group, maternal mortality was reduced from five to zero cases, while mortality among newborns decreased from nineteen to seven cases (dropped by 63%) compared to the control group.[13] The results promoted the expansion of the project that may increase the awareness of the advantages of ultrasonography, and thus the assurance and amenability of rural people regarding the health care system.[14]

Nevertheless, a great challenge is the scarcity of ultrasound technicians and physicians qualified to perform POCUS in remote regions. An innovative measure is to train midwives to perform POCUS in order to identify high-risk patients who can further be referred to the closest hospitals for additional management, similar to a triage service.[10] In rural Kenya, training of midwives to perform basic obstetric ultrasound investigations, and to transfer images and reports via the internet to physicians decreased the overall flow turnaround time by 10 minutes and promoted early identification of high-risk patients.[10] A report by Kozuki et al showed that with basic training on ultrasonography devices, health care workers in rural Nepal are now able to diagnose, with high precision, obstetric risk factors, leading to an estimated cost saving of $65 per patient.[15]

Compared to non-Aboriginal counterparts, maternal and infant health outcome in the Aboriginal population from Australia's Northern Territory is much poorer, as they receive less antenatal care, have a higher incidence of teenage pregnancy, preterm babies and low birth weight.[16] Gao et al investigated the health economics impact of a newly established Midwifery Group Practice (MGP) involved with the care of Aboriginal women from remote locations, transferred to a regional hospital for birth.[17] Compared with the baseline study group, women in the MGP group received more antenatal ultrasound screening, and were likely to be admitted to hospital for birth, followed by postnatal care in town. This initiative led to average cost savings of AU$703, making it cost-effective for remotely located Aboriginal women of all risks who chose to give birth in the hospital.[17]

Beside POCUS, there are other POCT that were shown to be beneficial for maternal, paediatric and neonatal care. For instance, preeclampsia and HELLP syndrome (haemolysis, elevated liver enzymes, and low platelet count) are health effects associated with pregnancy, leading to high morbidity and mortality incidences.[17] HELLP is particularly difficult to diagnose and manage, as it has an extremely fast progress, often leading to organ failures, coma or death in less than 3 hours. As such, early and accurate diagnosis is a vital prerequisite for patient survival.[18] A mobile phone–based point-of-care low-cost platform for detection of haemolysis was shown to provide life-saving benefits of a 10-minute turnaround time with a cost of approximately $1 per unit compared to more than 4 hours when using traditional laboratory (analytical) methods.[18]

Point-of-care testing in neonatal care for blood gases and electrolytes is another important aspect that was trialled in some settings. A low-cost POCT to determine arterial blood gases during cardiac catheterization was shown to improve clinical outcome in paediatric patients as it reduces turn-around time from 10 to 2.5 minutes, and thus shortens the interval to appropriate clinical interventions.[19] A study reported by Arthurs et al that aimed to compare the traditional blood measurement system with POC measurements using a blood gas analyser indicated a very good agreement between measurements, with a further advantage that multiple assays of POCT can be completed with smaller blood volume units compared with traditional laboratory assays, minimising sample handling and reducing unnecessary trauma to babies.[20] Moreover, the introduction of the POC analyser led to significant financial savings as the overall laboratory costs were reduced by £39,000 (−24.5%) per annum.[20] The cost-effectiveness of the multi-parameter Point-of-Care-blood test analyses was also confirmed by others.[21–23]

As already mentioned above, there are several factors explaining why women living in rural/remote communities are more vulnerable to pregnancy-related complications than women living in urban areas. The common causes leading to the differences in health care systems are the shortage of qualified personnel, and the scarcity of equipment and general health care facilities in rural areas.[7] A possible solution to this problem is telemedicine. A telemedicine system offers the delivery of health care services across a distance, thus improving the access to medical care and education, while improving the quality of care in remote areas that are underserved by health care professionals.[24] For instance, in Ghana, as in several developing countries, the distance from rural area to modern antenatal care (ANC) providers is probably the main reason for fewer ANC visits. In fact, 1 out of 9 women have to travel over 15 kilometres to receive medical care, which may contribute to more infant mortalities.[25] For health care workers at local health care facilities, the establishment of advanced telecommunication services via telemedicine could enhance the ANC management by enabling access to remote medical expertise.[25]

As presented before, obstetric ultrasound is a vital tool in monitoring the development of the foetus and assessing possible foetal problems. For a high-risk pregnancy, referral is subsequently required to a tertiary unit with a multidisciplinary team of specialists.[24] Unfortunately, referral is often hindered by several factors, including the shortage of tertiary referral units, the transport cost and time needed to reach the centre, and not ultimately, the emotional stress linked to all the above.[22] Indeed, a pregnant mother from rural Australia may need to take several hours to reach a regional centre from which to fly to a major city, where she requires an overnight stay before the multiple consultations are completed.[24] In this respect, a real-time foetal tele-ultrasound service was set up in Queensland, Australia, to allow patients from remote areas to be examined by specialists located 1500 km away, in Brisbane.[22] Cost–benefit calculations showed that the tele-ultrasound service resulted in a net saving of AU$6340 and increased the number of consultations by about 4, concluding that its use could be expanded in Australia to minimise the health care gap between rural areas and main cities.[24]

Point-of-Care Testing Related to Cardiovascular Disease

Cardiovascular disease (CVD) is the leading cause of death worldwide.[26] While public awareness combined with early treatment and preventive strategies resulted in a progressive decline in deaths caused by coronary artery disease and myocardial infarction (MI), the reduction has been less significant in rural and remote regions and there is still a massive proportion of health care expenditure on the management of CVDs.[27,28]

Hothi et al reported on the implementation of a "quick-scan" using a manual ultrasound device for bedside clinical assessment suited to multiple settings (including acute, emergency and intensive) that provide results within 5 minutes, enabling accurate diagnosis and risk stratification.[29] Spalding et al examined the efficiency of a POC device to determine a number of blood coagulation-related parameters during surgery, which was shown to substantially decrease the procedure costs (from €125,828 to €55,925), far outweighing the cost of the POCT.[30] Ferrada et al showed that image-guided resuscitation with limited transthoracic echocardiography can enhance the usage of health care resources in patients undergoing cardiac arrest by reducing the time spent in the trauma bay and avoiding nontherapeutic thoracotomy in non-surviving trauma patients.[31]

In the emergency department, any indecision or a poor clinical decision concerning the management of cardiovascular emergencies (such as acute coronary syndrome or congestive heart failure) can cause delays in life-saving interventions. Consequently, a rapid test of cardiac markers (≤30 minutes) is greatly required.[32] As shown by Blick, the employment of POCT for cardiac markers has resulted in significant improvement in clinical outcome, operational improvements, and economic benefits, with a dramatic reduction in inpatient hospital stay in coronary care units from 5.2 to 3.2 days and an estimated savings of over $1000 - per day per patient.[32] These results were confirmed by a similar study reporting the benefit and cost-effectiveness of troponin POCT in the diagnosis of acute myocardial infarction.[33] In contrast, a UK study reported a trial of POCT for cardiac markers, such as CK-MB, myoglobin and troponin, that lowered general inpatient costs but was correlated with higher expenses required in the emergency department and cardiac care, and thus are unlikely to be considered as cost-effective in the low-risk patient group.[34]

In rural South Australia, implementation of the Integrated Cardiac Assessment Regional Network (iCARnet) incorporating POCT for troponin has perfected the clinical support for practitioners and patients' outcomes for rural patients.[26] Through this regional health network program, the 30-day readmission rate for acute coronary syndrome was reduced from 10.4% to 4.2% and the hospital death rates for the same condition dropped from 15.8% to 9.8%.[28] Adequate training and implementation of POCT for troponin that integrates with treatment enables accurate and prompt diagnosis and risk stratification, facilitating optimal patient management. This POCT was safely implemented in multiple health care settings across a wide geographic area.[28] Table A3.2 is a compilation of studies and their findings concerning POCT in cardiovascular disease.

Point-of-Care Testing Related to General Clinical Diagnosis

According to the Australian Government's 2015 report, next to cardiovascular disease Indigenous Australians commonly suffer from long-term respiratory disease (31% of Indigenous people), diabetes (11%) as well as chronic kidney disease (16% of deaths are associated to kidney disease).[1] The following section presents some evidence of POCT management across the world in relation to the aforementioned conditions.

Of all medical imaging methods that could be employed in locations with limited resources, ultrasound remains the best option due to its portability, efficiency, affordable price and safety.[35] POCUS was implemented for a wide variety of conditions in resource-limited health care settings (see also Table A3.3) including sepsis, non-traumatic shock, respiratory failure, and acute decompensated heart failure, though it still requires a comprehensive cost-benefit analysis.[35–38]

Blattner et al assessed the effect of POCT on health economics in a rural hospital in northern New Zealand.[36] The study showed that POCT significantly improved diagnostic accuracy for 43% of patients, thus decreasing the number of transfers to the base hospital by 62% and increasing hospital discharges by 480%. This exercise led to an overall financial benefit of NZ$452,360 annually.[39] Similarly, in Australia's Northern Territory the implementation of POCT during 6 months averted 60 medical evacuations from 200 cases of chest pain, missed dialysis and acute diarrhoea, cost savings that when translated to the whole Northern Territory would add up to AU$21.75 million in total.[2] Contrastingly, another Australian study revealed that while POCT significantly decreased patient costs related to time and travel to a health care facility, it increased the number of tests and general practicians visits per person annually, which cancelled out the cost savings achieved with the implementation of POCT.[40]

The use of haemoglobin A1c test (HbA1c) to monitor blood glucose levels in diabetic patients is the standard of care in developed countries and is becoming increasingly popular throughout the world as a point-of-care test in primary care units.[41] A study in the US showed that the implementation of an interface between the POCT blood sugar device, a data management system and the hospital information system, increased operator compliance and reached cost savings of up to $119,095 annually.[42]

Another type of POCT for diabetes is self-monitoring of blood glucose levels, though the cost-effectiveness of this measure is still uncertain. While a study in the UK revealed that self-monitoring was unlikely to bring cost benefits in addition to standard care,[43] a report from the US showed that the cost-effectiveness tends to increase in long-term implementation.[44]

The use of POC system in emergency departments which allows rapid analysis of blood samples was shown to result in a substantial saving of $111 per patient, thus totalling $7,350,000 per year in the health care setting.[45] Taking into account the likely saving on hospital waiting times, this system could, in addition, improve patient safety and assist in the decongestion of overcrowding in the emergency departments.[45]

According to Lewandrowski et al, an initial POCT menu offered on the day shift for 5 days weekly which included a series of tests such as whole-blood glucose and cardiac markers, urine dipstick and pregnancy testing, resulted in 87% decrease in test turnaround time and a shortening of hospital stay down to an average of 41.3 minutes per patient.[43] The expansion of the menu with additional tests for rapid influenza, rapid RSV, rapid Strep A, urine test for drug abuse and whole-blood D-dimer with operation on 7 days, 24 hours per day, ED efficiency was further improved.[46]

The role of POCUS for respiratory disease was analysed by two studies, with one Canadian report showing a drop in costs for total hospital stay and lower incidence of haemorrhage and pneumothorax,[47] and another US study demonstrating better management plans for patients with pneumothorax or respiratory abnormalities with POCUS in place.[48]

A study in Thailand concluded that the concurrent use of POCT, microscopy and urine dipstick improved the diagnosis of urinary tract infections which allowed prompt and correct prescription of antibiotics[49] to prevent further kidney disease.

Implementation, Monitoring and Limitations of POCT in Australia

As shown above, POCT could potentially reduce costs, enhance workflow efficiency and improve patient care by enabling more prompt diagnosis and treatment decisions, cost-saving technology solutions and wireless connectivity. A limited number of studies indicated that the implementation and sustainability of POCT requires higher costs as compared to traditional approaches, though at the same time it was reasoned that the POCT-associated expenses could actually be justified by long-term benefits to the entire society, such as better health monitoring, decreased hospital stay and prolonged healthy life.[50]

Nevertheless, it is acknowledged that the economic value of POCT depends on the prevalence of a specific disease. In Australia, for example, women who lived in urban areas had a maternal mortality rate (MMR) of 6.8, while those who lived in rural and remote regions as well as Aboriginal and Torres Strait Islander women had a MMR of 9.6 and 31.6 per 100,000 women who gave birth, respectively.[51] Consequently, introduction of POCT, especially POCUS and telemedicine, in rural and remote Australia may bring a positive change in maternal care.

One of the challenges of POCT is to ensure quality assurance of the testing process. In this regard, laboratory personnel must provide appropriate assistance for the implementation of POCT to warrant reliable results and patient safety, whereas tertiary hospitals should develop guidelines and a system for managing quality standards, training of operators and regular reaccreditation programs.[38,52]

Among the selected literature, there are large variations in the study design. Sample size is different while the target population is varied in age, gender, ethnicity, health status, etc. With different diseases reported, the prevalence rate varies in different populations or communities. Several types of health economic analysis and outcome reporting method were identified, with various thresholds and definitions being used for "cost-effectiveness" of specific POCT. Furthermore, a number of studies did not mention long-term outcomes, which may create bias when comparing newly implemented POCT and current standard measures. POCT may become more effective if long-term effects are accounted for.

POCT design, outcomes and economics are also strongly linked to economic status. For example, as shown in Table A3.1, ultrasound-based POCT is the most commonly implemented type of POCT in developing countries, while biomarker/lab test-based POCT is prevalent in developed countries. Similar observation can be drawn from Table A3.3 which includes a summary of POCT testing for general clinical diagnosis, whereas cardiovascular POCT (Table A3.2) is dominant in developed countries.

Last but not least, studies undertaken in developing countries may not be able to provide a good reference for the conditions in Australia. Bias may occur since the quality of health care, the level of training, the number of health care workers and prevalence of diseases are different between developing and developed countries. Further studies evaluating the situation in rural and remote areas of developed countries are required in order to reach pertinent conclusions translatable to the Australian setting

Conclusion

Based on current findings, POCT is generally beneficial with potential promising health results, and it could be considered by various health policies as one of the potential approaches to manage health risks in remote, rural and vulnerable populations. It is also clear that the benefits in terms of economic outcomes vary for different diseases and settings. Therefore, a comprehensive cost-benefit evaluation is required prior to the implementation of a specific POCT in a particular disease, for a targeted population or community.

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