


ORIGINAL ARTICLE

The viability and acceptability of a Virtual Wound Care Command Centre in Australia

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Abstract

The objective of this study was to assess the viability and acceptability of an innovative Virtual Wound Care Command Centre where patients in the community, and their treating clinicians, have access to an expert wound specialist service that comprises a digitally enabled application for wound analysis, decision-making, remote consultation, and monitoring. Fifty-one patients with chronic wounds from 9 centres, encompassing hospital services, outpatient clinics, and community nurses in one metropolitan and rural state in Australia, were enrolled and a total of 61 wounds were analysed over 7 months. Patients received, on average, an occasion of service every 4.4 days, with direct queries responded to in a median time of 1.5 hours. During the study period,

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26 (42.6%) wounds were healed, with a median time to healing of 66 (95% CI: 56-88) days. All patients reported high satisfaction with their wound care, 86.4% of patients recommended the Virtual Wound Care Command Centre with 84.1% of patients reporting the digital wound application as easy to use. Potential mean travel savings of \$99.65 for rural patients per visit were recognised. The data revealed that the Virtual Wound Care Command Centre was a viable and acceptable patient-centred expert wound consultation service for chronic wound patients in the community.

KEYWORDS

chronic wounds, digital wound application, telehealth, virtual care, wound care

Key Messages

- Translating the use of a digital wound application platform to provide effective wound care through a new virtual model of care is critical to improving access and a continuum of evidence-based care to patients with chronic wounds.
- The aim of this study was to evaluate the viability and acceptability of a Virtual Wound Care Command Centre utilising a digital wound application platform across four specialities in metropolitan and rural services in one state in Australia.
- All patients reported a high degree of satisfaction with the Virtual Wound Care Command Centre in relation to direct and ongoing access to specialist care, monitoring, improved confidence, and reduced travel time and savings.
- Remote monitoring of wounds did not decrease the quality of, or access to, care; it yielded a median clinician-to-patient response time of 1.5 hours for wound triage and care plan development.

1 | INTRODUCTION

Living with a chronic wound carries significant unrecognised burden that impacts the individual, their family, and health care utilisation. The presence of a chronic wound is associated with increased length of hospital stay,^{1,2} higher risk of infection,³ and increased readmissions within 30 days due to wound complications²; leading to poor health-related quality of life. An Australian qualitative study of 25 patients with chronic wounds in the community found chronic wounds impacted a person's physical mobility, finances, and ability to maintain work.⁴ In addition, a cross sectional study of 222 patients with chronic wounds in New York revealed that moderate to severe depression was experienced by patients with wounds beyond 3 months.⁵

It is estimated that 345 000 people in Australia live with chronic wounds, costing the health care system \$2.85 billion annually.⁶ More recent data suggests that chronic wound incidence and prevalence are under-reported in Australia, largely due to different types of

wounds being reported in specific populations and the wide variations in reporting.⁷ In the United Kingdom, an estimated 2.2 million chronic wounds are managed by the United Kingdom's National Health Service every year.⁸ Chronic wounds are reported to affect 2% of the population in the United States.⁹

Current standard wound care in Australia is complex, with lack of standardisation in wound assessment, interventions, and clear clinical pathways, in addition to, uncoordinated services with poor communication,³ lengthy delays between specialist appointments,³ and inequitable access to quality wound products.¹⁰ Medical record systems are also inadequate for documenting wound data, with existing systems not designed to track or store wound images or generate wound reports and patient confidentiality is potentially breached when clinicians take images on personal devices.¹¹ These factors contribute to poor wound-healing outcomes in Australia and support a case to create more patient-centred models of care in the community for patients with chronic wounds.

The recent experience of the COVID-19 pandemic in our health service required transition, where possible, to a telehealth model of care (MoC), reducing risks to patient by limiting face-to-face contact in clinical settings. For the individual with a chronic wound, this was not feasible, leading the authors to establish point of care access to specialist services via a virtual wound MoC with complementary digital services for patients with chronic wounds. Virtual care (a broader term for telehealth or telemedicine) is a MoC that offers a wide range of digital services that assist in delivering care to people remotely.¹² It includes the use of telephones, video conferencing, monitoring, and store-and-forward communication platforms.

Studies on virtual care models for patients with chronic wounds are limited. From the few available studies on patients with chronic wounds and quality of life outcomes, virtual care has been demonstrated to be safe and effective in wound-healing, improving access to care and confidence in patients.¹³⁻¹⁵ A recent systematic review conducted by Huang and colleagues¹⁴ summarised the evidence available and assessed the efficacy of telemedicine for chronic wound care across 14 randomised control trials. The researchers found telemedicine had a positive effect on chronic wound outcomes as it facilitated wound-healing and reduced adverse events when compared to usual care. Chen and colleagues¹³ systematic review of 58 studies evaluated the efficacy and safety of telehealth in chronic wound care. They found that the available evidence demonstrated telehealth to have similar wound-healing efficacy and safety when compared to face-to-face care.

The New South Wales (NSW) Virtual Care Strategy (2021-2026) published by NSW Health sets out a plan to support all health services to develop local telehealth strategies and virtual MoCs. The aim is to achieve accessible and efficient quality of care for patients irrespective of where they live. To do this, virtual care services must complement face-to-face care.¹⁶

In our health service of four hospitals and five community centres, a virtual care service for remote patient monitoring was launched in 2020 to provide additional pathway of care between primary care providers, individuals, and tertiary centres, where this model provides an opportunity to improve patient centred care. The virtual care service caters for (a) people in the community who are immune-suppressed; (b) mental health patients; (c) patients of the fracture clinic; and (d) COVID-19 patients in home isolation.^{17,18} Almost 4000 people were cared for in the first year of its launch with patients reporting a high degree of satisfaction, particularly in relation to being monitored virtually, increased confidence in their own care, and improved access to specialist services.¹⁹

Our previous study,²⁰ conducted in one health service in Australia, tested the acceptability and effectiveness of the Tissue Analytics™ digital wound application (digital app)²¹ among clinicians. The study found that the digital app improved documentation and data management of wound care. Clinicians found the application was easy to use, assisted with objective wound assessment, and provided benefits by improving connectivity and continuity of care for patients in the community. The study identified an opportunity for further research into the feasibility of utilising a digital wound application to establish a new virtual service that would provide remote access to specialist wound care for individuals with wounds, specifically chronic or complex wounds. This article presents the findings from a translational study on the viability and acceptability of utilising the digital app in a Virtual Wound Care Command Centre (eWCC); a new MoC to improve wound care for individuals in the community across four specialties: vascular, podiatry, specialist wound services, and community nursing in metropolitan and rural NSW.

2 | MATERIALS AND METHODS

2.1 | Study design

This was a prospective, observational study to test the viability and acceptability of an eWCC supported by a digital application, namely Tissue Analytics™ (Baltimore, Maryland, <https://www.tissue-analytics.com>). Tissue Analytics™ is a purpose-designed digital wound management platform that provides tools to record, track, and analyse patient wounds,²¹ and is referred to as the 'digital app' from this point forward. Participants were recruited to the study between 17 December 2020 and 28 May 2021, and wound data were collected until the wound healed or end of data collection on 6 August 2021.

2.2 | Study setting

The study was undertaken across four different specialities (nine centres) in metropolitan and rural health services in one state, NSW, in Australia that provides services to patients with wounds. The specialties include podiatry and vascular outpatient clinics, general community nursing, and specialised wound services such as vascular and endovascular surgery. There were 19 wound specialists (nurse specialists, podiatrists, doctors, surgeons) across the nine centres who were responsible for enrolling and monitoring

patients in the eWCC. A shared care plan was developed between the wound specialist and treating general practitioner (GP) or community nurse.

blind-ended track such as pilonidal sinus and sinus); (b) a wound that required specialised treatments such as a burn; or (c) a superficial, fast healing wound that requires <1 week for wound closure.

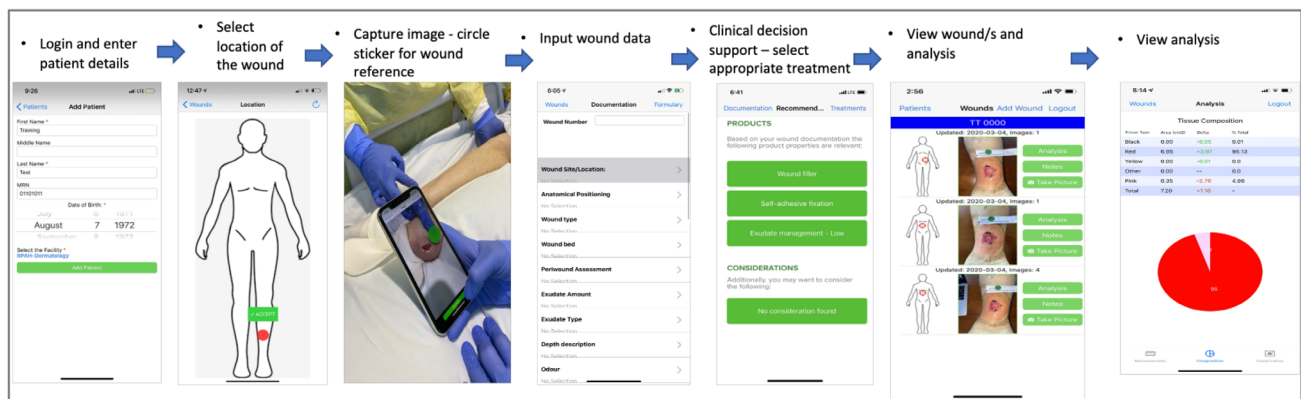
2.3 | Participants and recruitment

Participants with a wound(s) and ≥18 years of age were invited to participate in the study. Participants were excluded if they had: (a) a non-healing wound (eg, palliative, malignant, or fungating tumours; wounds with a

2.4 | Standard usual care

Patients with wounds discharged from hospital who are referred to community nursing are triaged and on average, if not urgent, are seen within 2 weeks. If the wound

(A) Clinician interface - phone



(B) Clinician interface - portal



(C) Patient interface - phone

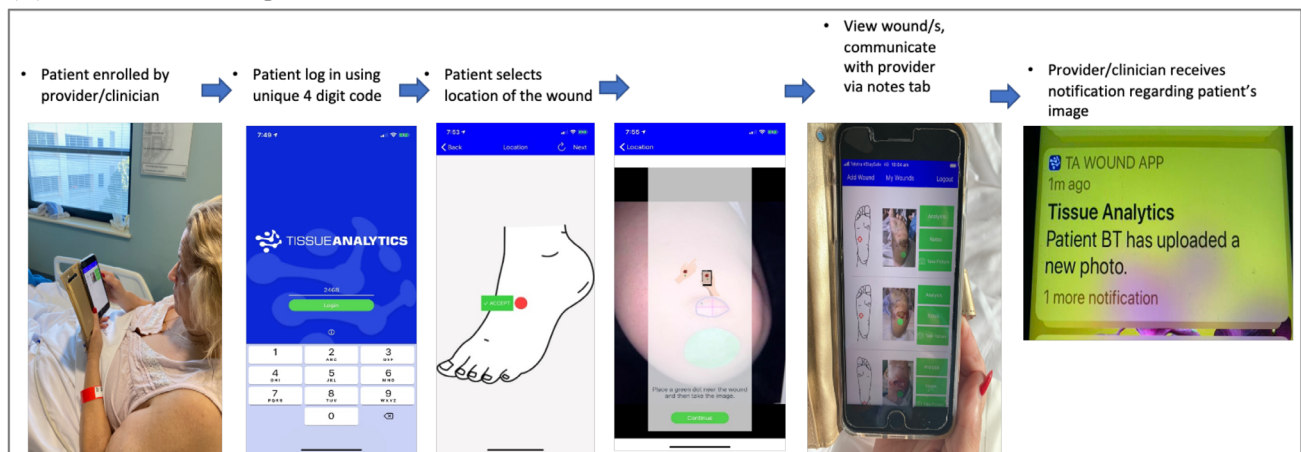


FIGURE 1 Tissue Analytics™ digital wound application platform comprising of a (a) clinician mobile phone interface, (b) clinician web portal interface, and (c) patient mobile phone interface

is complex or not healing, the community nurse will request a joint visit with a specialist wound nurse. Specialist wound nurses are only available through direct referral from clinicians. Further, patients are unable to call or email specialist wound nurses for quick access. Patients who have follow up with their treating GP or an outpatient clinic or follow-up with a surgeon experience long waiting periods between visits as they must either wait for their appointment to see their treating clinician, or they wait for the treating clinician to make a visit—the latter for patients with mobility difficulties. In all cases, patients experience delays in receiving specialised wound services.

2.5 | Intervention—The Virtual Wound Care Command Centre

The eWCC is an interdisciplinary nurse-led specialist care and support service, available to patients and their treating GP or nurse, which enables the application of treatment plans for people with chronic wounds in the community. The eWCC comprises: (a) coordinated services of advanced wound specialists accessible to the patient, their carer, or treating nurse/GP; (b) continuity of care for patients who are discharged from hospital, into the community; (c) a comprehensive treatment plan by the wound specialists; (d) a purpose-designed digital app with real-time imaging of wounds²¹ comprising a patient interface and a clinician interface (Figure 1); (e) audiovisual communication connection to a command centre for the patient to allow prompt access/response for the treating clinicians (wound specialists, treating nurse/GP) or patient/carer to ensure early recognition of deterioration; and (f) a centralised database for benchmarking and generating reports. Patients are supported by their treating clinicians and instructed on what to do in an emergency. Patients are also handed an instructional information brochure with clinician contact details should either technical or clinical issues arise. As such, the use of the digital app did not replace required visitations to the treating clinicians but complemented these visits by providing additional support in between appointments. Lastly, there is a secure messaging function within the digital app for communication between the patient and the treating clinicians.

2.6 | Outcome measures

The primary outcome was the viability and acceptability of the eWCC, patient usability of the digital app, and efficacy of remotely monitoring wound care. Other outcomes included number of wounds healed (defined as the epithelial tissue covering 100% of the wound), wound-

healing rate, and potential travel-related time and cost savings, and carbon footprint avoided.

2.7 | Study procedure

Wound specialists (nurse specialists, podiatrists, doctors, surgeons) in the study units were trained to use the digital app. Training consisted of two sessions: one for the clinician interface and web portal, and one for the patient interface. The wound specialists assessed patients for eligibility and enrolled them in the study as participants. Informed written consent was obtained from patients prior to enrolment. Participants were trained by their wound specialist to download and use the patient interface of the digital app. They were provided with a written information sheet and the contact details of their wound specialists for questions.

For enrolment, the wound specialists added the participant as a user in the digital app system by entering their details, taking an image of the wound, and inserting wound information into the digital platform using the clinician interface of the app. The participant would then use the app to take successive images of their wound and enter wound characteristics such as pain and ooze. When participants used the digital app to photograph their wound and input wound information, their wound specialist received a notification to review the report and triage as appropriate. The wound specialists would then enter data on the treatment plan and respond to the participant. In this way, the digital app was used as a tool to support remote wound care assessment and management. As this study was an observational study, the digital app was not integrated with the electronic medical record (eMR). Instead, wound documentation was generated into a PDF document and uploaded into the patient's eMR to maintain record keeping.

Participants enrolled in the eWCC were invited by their wound specialist at the first consultation and last consultation to complete a survey on their satisfaction with the wound care they received. The surveys were conducted anonymously and completed on paper or via a survey link. They were also invited to participate in an interview to share their views and experiences of wound care via the eWCC and digital app. Interviews were conducted via phone by one of the researchers and lasted approximately 15 minutes.

2.8 | Data collection

Each participant was assigned a unique identifier to ensure patient confidentiality during data collection and analysis of de-identified data. Re-identifiable coded data were

stored on the University of Sydney's secure online REDCap (Research Electronic Data Capture) database,^{22,23} accessible only to the study investigators. REDCap is a secure, web-based software platform designed to support data capture for research studies, providing (a) an intuitive interface for validated data capture; (b) audit trails for tracking data manipulation and export procedures; (c) automated export procedures for seamless data downloads to common statistical packages; and (d) procedures for data integration and interoperability with external sources.

2.8.1 | The Virtual Wound Care Command Centre Occasions of Service

The occasions of service (OOS) administered by the eWCC were collected by the digital app platform. An occasion of service is defined as any examination, consultation, treatment, or other service provided by a clinician in a non-admitted setting to a client/patient. Each wound image and text note communicated using the digital app platform was counted as an OOS.

2.8.2 | Participant surveys

Two participant surveys were administered. The first survey administered at the beginning of the study to capture participant satisfaction with their wound care under standard usual care practices and the survey was repeated at the end of the study to capture participant satisfaction with their care through the eWCC. To capture usability and acceptability of the digital app, a second survey comprising of 12 questions were added to the first survey and was administered at the end of the study. This second survey was based on a telehealth satisfaction instrument developed by Fatehi and colleagues.²⁴ The survey questions were constructed using a five-point Likert scale, including the options: strongly disagree (scoring 1 point); disagree (scoring 2 points); neither agree nor disagree (scoring 3 points); agree (scoring 4 points); and strongly agree (scoring 5 points). They were piloted with two consumers on the research team, prior to finalising the survey. Surveys were kept anonymous. All surveys were captured using the REDCap electronic data capture tools hosted at the University of Sydney.^{22,23}

2.8.3 | Participant interviews

Participant interviews continued until data saturation was reached at 10 interviews. The interviewers asked the participant to express their overall experience with virtual wound

care and the digital app, prompting them to highlight things they liked or did not like and how it affected their wound care. The interviews were recorded using either Windows Media Player or Apple Voice Memos and the recordings were transcribed verbatim by Digital and Audio Transcription Services (DAATS, Australia).

2.8.4 | Wound data

Characteristics of wounds, including wound type, wound size, and change in wound characteristics over time, were captured and downloaded from the digital app. All participants' wound data were de-identified when recorded and entered into REDCap.^{22,23}

2.8.5 | Impact on travel

At the end of the study, participants were asked about their mode of transportation to estimate travel distance, time, and fuel costs. The Green Vehicle Guide (<https://www.greenvehicleguide.gov.au/>) was used to collect data on the vehicle's fuel consumption and fuel emissions. Cost of fuel was determined using NRMA fuel report data for NSW (<https://www.mynrma.com.au/membership/my-nrma-app/fuel-resources/weekly-report/>). For participants who commuted by public transport or used commercial passenger vehicles, the average fare cost for a trip was recorded. Travel time and distance were estimated using Google Maps.

2.9 | Data analysis

2.9.1 | Occasions of service

The number of OOS per participant was recorded and tabulated against their duration of enrolment. Linear regression was conducted to determine the average OOS frequency per participant.

The digital app recorded the date and time of all images and text communications. From this data, the response time was calculated to assess the efficiency in using the digital app as a mode of communication between the wound specialist and patient participant. The response time is defined as the time between communication events involving the participant and their wound specialist.

2.9.2 | Participant surveys

Questions from the surveys were grouped into five categories. Survey outcomes were calculated by adding the

scores of each question of the survey and then calculating the mean score of each category. The percentage of responses for each Likert scale value for the questions in each category was also graphed for analysis. Comparison in satisfaction survey scores was used to assess participant experience with the eWCC compared to the usual care they had previously experienced. Survey scores for the digital app were used to assess participant usability and acceptability of the digital app.

2.9.3 | Patient interviews

Interviews were analysed using Braun and Clarke's guidance. Thematic analysis²⁵ was conducted in six steps: familiarisation with data; generation of initial codes; search for themes; review of themes; definition and naming of themes; and preparation of a written report. Data analysis was undertaken by three team members (M.B.J., B.K., K.W.) independently to ensure rigour.

2.9.4 | Wound data

Percentage change in wound surface area (SA) for each participant's wound was calculated using the difference in wound SA evaluated from date of enrolment to last wound evaluation date for the participant. Healing rate was expressed as the advance of the wound margin towards the wound centre per day, as this calculation allows comparison of healing rates between wounds independent of initial wound size or shape; using the calculation below.²⁶

Healing rate

$$= \frac{2(\text{final area} - \text{initial area})}{(\text{final perimeter} - \text{initial perimeter})(\text{no. of days})}$$

For wounds decreasing in size, the healing rate is a positive value, while a negative value was given to those wounds that increased in size.

2.9.5 | Impact on travel

Cost of travel for participants using private vehicles was calculated using the fuel consumption data of the vehicle (L/km), the distance travelled (km), and average fuel cost of AUD1.346/L over the period of the study. For participants who commuted by public transport or used commercial passenger vehicles, cost of travel was calculated as the average fare cost. Mean travel time

was calculated by averaging the minimum and maximum travel times provided by Google Maps at 9 AM, 12 PM, and 3 PM. Fuel emissions were calculated using the CO₂ emissions data (g/km) for each vehicle and the distance travelled (km). Carbon footprint was determined using the estimation that one mature tree offsets on average 0.0029 t carbon dioxide per year (<https://trees.org/carboncalculator/>).

All data were entered into GraphPad Prism (v9.2.0). As an acceptability and viability study, no a priori sample size calculation was conducted. Convenience sampling was used for patient sampling. Patient demographic and clinical data were analysed descriptively using frequencies and percentages (for categorical measures), and means and SDs (for numerical measures).

Inferential statistical analysis on wound percentage decrease and healing rates was not conducted between different wound groups due to small numbers within each group. As an acceptability and viability study, the analysis was underpowered to detect significant effects.

2.10 | Ethical consideration and trial registration

The study was conducted in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research. The study was approved by the local institutional review board. Written consent was obtained from all participants included in the study. The trial was registered on ANZCTR, registration number ACTRN12621000344897.

3 | RESULTS

3.1 | Participant enrolment and demographics

A participant eligibility and enrolment flow chart is displayed in Figure 2. A total of 51 participants were enrolled in the eWCC and data were collected for up to 7 months. From these participants, data on 61 wounds were analysed.

Demographic and clinical participant characteristics are summarised in Table 1. Participants enrolled in the study were aged from 30 to 91 years, with a mean age of 61.9 years (SD 13.4 years). The proportions of male and female participants were approximately equal (53% male and 47% female). Over half the participants were diagnosed with either a metabolic or a

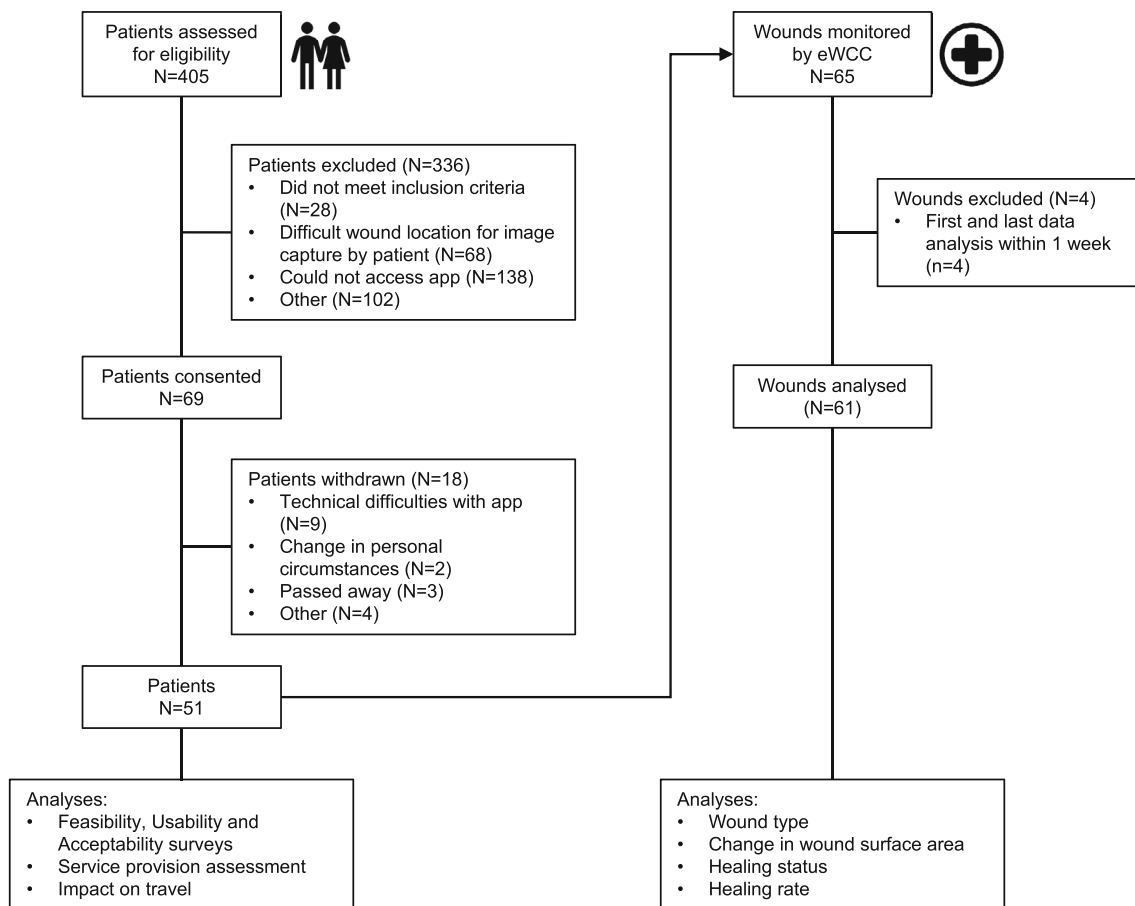


FIGURE 2 Flow chart for participant enrolment and wound monitoring

circulatory system disorder and were being treated for a chronic ulcer.

3.2 | Occasions of service

Over a period of 229 days, a total of 828 OOS was provided to 51 participants through the eWCC. Linear regression analysis showed each participant received on average one occasion of service every 4.4 days ($r^2 = 0.55$), in addition to any phone calls that were conducted but not captured in the study.

Participants used the notes function of the digital app to communicate with the wound specialist. All communications through the notes function were recorded on the digital platform and could be reviewed by the wound specialist at any time. In turn, the wound specialist could respond to the participant through the notes function. The time of response for each of these communications is displayed in Figure 3. Approximately 50% of communication notes were responded to within 2 hours by the wound specialist, and a median response time of 1.5 hours was calculated.

3.2.1 | Participant survey - Wound Care Service

At the beginning of the study period, a total of 55 surveys out of 69 consents (79.7% response rate) were received. At the end of the study period, participants still enrolled in the eWCC were asked to complete the survey again to assess their satisfaction with the eWCC compared to previous experiences. A total of 44 participants out of 51 completed the end of study survey, a response of 86.3%.

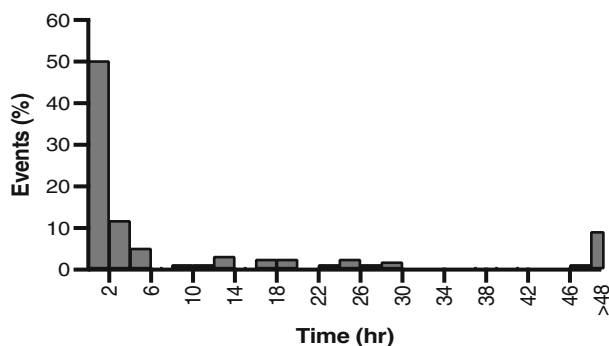
There was diversity in treating clinicians providing wound care services with up to one-third of participants seeing multiple clinicians to treat their wounds (Table 2). Once participants were enrolled in the eWCC, a shared care plan (patient-centred health care plan that is shared by several members of a care team), was initiated.

Survey scores for wound services at baseline (that is, before enrolment into the eWCC) were between 4 and 5 for all but one category (Table 3). The highest mean item score was for wound care services (4.8) and the lowest was for ease of travel (3.8). Participant survey scores did not change in each of the categories following their

TABLE 1 Demographics and clinical characteristics of participants

Gender	N (%)
Male	27 (53%)
Female	24 (47%)
Age	Mean (SD)
Age (y)	61.9 (13.4)
Participant diagnosis	N (%)
Endocrine, nutritional and metabolic disorders	20 (32.3%)
Circulatory system	15 (24.2%)
Skin, subcutaneous tissue and breast	3 (4.8%)
Neoplastic disorders	2 (3.2%)
Infectious and parasitic diseases	2 (3.2%)
Musculoskeletal sys and connective tissue	2 (3.2%)
Kidney and urinary tract	1 (1.6%)
Digestive system	1 (1.6%)
Hepatobiliary system and pancreas	1 (1.6%)
Mental diseases	1 (1.6%)
Injury, poison, and toxic effect drugs	1 (1.6%)
None	2 (3.2%)
Wound types	N (%)
Venous ulcers	19 (31.1%)
Diabetes-related foot ulcers	17 (27.9%)
Postoperative wounds ^a	7 (11.5%)
Surgical dehiscence	5 (8.2%)
Pressure injuries	4 (6.6%)
Skin tears and lacerations	2 (3.3%)
Skin grafts	2 (3.3%)
Sinus	1 (1.6%)
Stasis	1 (1.6%)
Other	3 (4.9%)

^aPostoperative wounds that are complex due to size of wound, wound location, or underlying illness of participant.

**FIGURE 3** Frequency distribution of response time by clinicians on the digital app to participants following receipt of an image or note**TABLE 2** Treating clinicians/settings where participants (n = 55) were seen for their wound care prior to enrollment in the Virtual Wound Care Command Centre

Treating clinician	Patient response number (%)
Wound specialist at the hospital	13 (23.6%)
Local general practitioner	1 (1.8%)
Community nurse	11 (20.0%)
Outpatient clinic at the hospital	12 (21.8%)
Other (patient self-management, surgeon, hospital department)	6 (10.9%)
Combination of two or more of the above	12 (21.8%)

TABLE 3 Participant survey on the wound care service, the categories and scores based on Likert scale (1: strongly disagree to 5: strongly agree)

Survey categories for wound care	Mean score	
	Baseline	Post eWCC
Perception of care services	4.8	4.9
Timely access to wound care services	4.6	4.8
Ease of communication with wound specialist	4.6	4.7
Ease of travel and seeing the wound specialist	3.8	3.8
Self-empowerment and confidence to manage own wounds	4.6	4.7
Preference for face-to-face consultation	4.5	4.3

Note: The survey was administered at the time of enrolment (baseline) and at the end of the study (post Virtual Wound Care Command Centre [eWCC]).

enrolment into the eWCC, again scoring highest for wound care services (4.9) and lowest for ease of travel (3.8).

Although baseline data were favourable to start with, a higher percentage of participants scored a 4 or higher post eWCC in categories for timely access (98.5% vs 91.7% at baseline), ease of communication (97% vs 90.3% at baseline), and ease of travel (69.5% vs 65.5% at baseline) (Figure 4). In addition, while 89.1% of participants said they preferred face-to-face consultations at the start of the study, this reduced to 72.7% after the study, with 25% of participants scoring impartially (neutral) to this question (Figure 4).

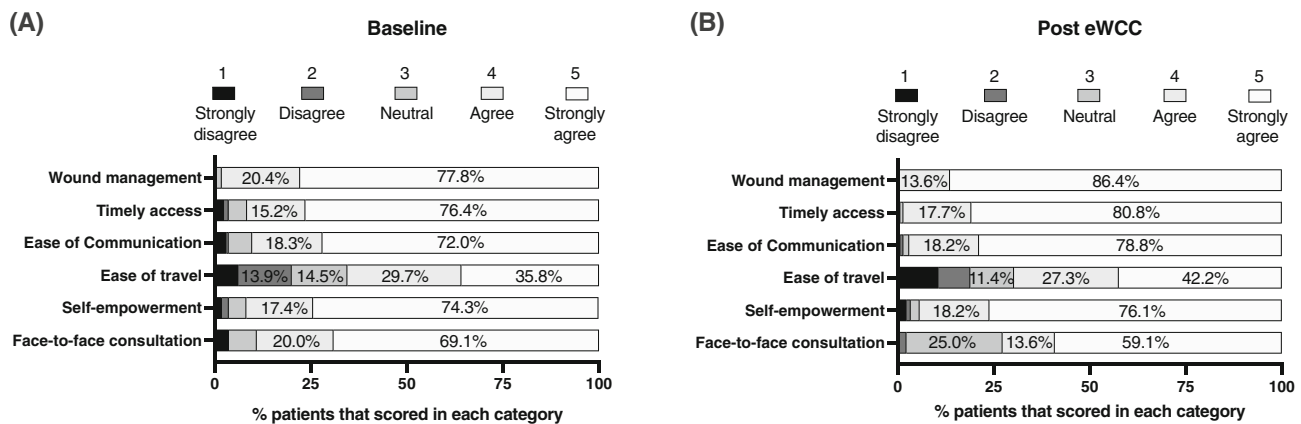


FIGURE 4 Participant survey results at (a) the time of enrolment (baseline) and (b) the end of the study (post eWCC). Data presents percentage of participants that scored in each Likert scale category. eWCC, Virtual Wound Care Command Centre

3.2.2 | Participant interviews

In presenting the data, a pseudonym was assigned to participants to maintain their confidentiality. Two themes were identified from participant interviews that reflect their experiences in relation to the eWCC: (a) connectivity is valuable for ongoing access to, and confidence in, wound care; and (b) remote consultation complements face-to-face visits.

Connectivity is valuable for ongoing access to, and confidence in, wound care

A common benefit that participants expressed about having their wound managed through the eWCC was their connectivity to a wound specialist. Participants found it comforting and reassuring that they could communicate with the wound specialist at any time and receive a timely response. This was particularly valued by people who lived remotely or found it inconvenient to travel. Tracy, a 49-year-old with a venous ulcer said:

Wound specialists were very knowledgeable and would respond to questions in a fast time.

Ben, who was 33 years old and had a dehisced surgical wound stated:

Someone who's probably alone or doesn't have that regular follow-up by a nursing professional, this would probably help because at least you've, kind of—you don't need to wait so long to get feedback, or you don't feel like you're out of contact which generally helps because you can at least get a faster response if you're worried about something.

Participants also found that this connectivity gave them the confidence to manage their wounds. They felt that having an open line of communication with their wound specialist alleviated concerns and provided reassurance about their wound dressings and healing progress. Anita, who was 52 years old and had a liver transplant, developed a clot that had resulted in a very deep wound, explained:

So, for me to actually go to the hospital to be treated, but also have the confidence and reassurance to leave there and know that if something did happen, I could actually monitor it myself and communicate with ... the wound care professional, was just so, so good, as I said, so reassuring and just left me with that confidence.

Nellie, a 61-year-old who had bilateral forefoot amputation wounds and lived in a rural community disclosed:

We were flying blind because nobody's dealt with forefoot amputations out here. And what did we do and what to expect sort of thing ... is this good or is this bad or is this something that we need to do ... to have that contact and ability to talk to [wound specialist] and converse with [wound specialist] for suggestions about what to do or, you know, *et cetera* was great. It really was ... [wound specialist] did ring me a number of times as well.

Remote consultation complements face-to-face visits

Participants commented that virtual care was very convenient for those who were not mobile, or needed to travel

long distances, in times when lockdowns prevented participants from travelling. Jean, the age of 59 years, was a patient of the high-risk foot clinic stated:

I just think it's a very good idea for people that aren't mobile and don't need to be seen face-to-face regularly.

Morris who was 64 years old with peripheral vascular disease and had vascular ulcers explained:

And with the thing of COVID sometimes we can't get there because of the lockdown. So, by having the use of that app, usually we dressed it at night. My wife will take the picture, she does the dressing and that. She can send it to [wound specialist] and we'll probably have an answer within a quarter of an hour.

Some participants enrolled in the eWCC were also making scheduled visits to the wound specialist as part of their programme. In this setting, participants noted that the remote service complemented the scheduled visits and, at times, reduced the number of face-to-face visits.

John, aged 44 years, who had a diabetic foot ulcer stated:

...it's a tool that the people who are treating your wound should introduce and use that to reduce face-to-face consultations.

Tom, aged 68 years old, with peripheral vascular disease and a postoperative foot wound explained:

They'd tell me if they—once they saw the photos, they didn't want to see me, they would call me and say—in the end, it went from once a week to every two weeks.

3.3 | Usability and acceptability of the digital app

3.3.1 | Participant survey - Digital app use

Participant survey scores and percentage response to questions on the digital app are shown in Table 4 and Figure 5, respectively. Participants rated the use of the digital app and its effectiveness in wound management very favourably, with average scores of 4.0 and above recorded in the respective categories (Table 4). A total of 84.1% of participants found the digital app easy to use, 86.3% of participants agreed it was a tool to support face-to-face

TABLE 4 Participant survey on the digital app; score based on Likert scale (1: strongly disagree to 5: strongly agree)

Survey categories for the digital app	Mean score
Ease of use	4.2
Timely access to wound care services	4.0
Ease of communication with wound specialists	4.0
Reducing travel to see the wound specialists	3.6
Self-empowerment and confidence to manage own wounds	4.0
Supporting face-to-face consultation	4.4
Recommended for wound care management	4.5

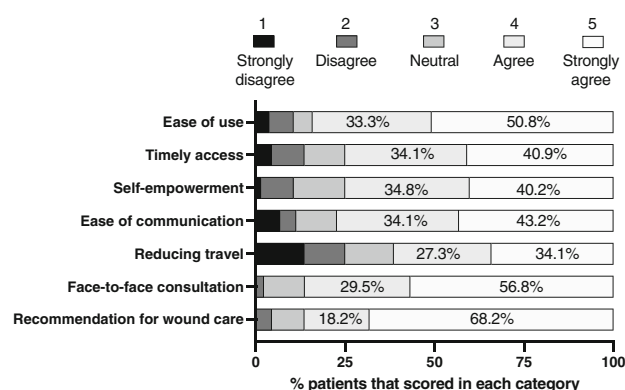


FIGURE 5 Participant survey results on the digital app for wound care management. Data shows percentage of participants that scored in each Likert scale category

consultations, and 86.4% of participants recommended the digital app for wound care management (Figure 5).

3.3.2 | Participant interviews

The narrative themes regarding the digital app from participant interviews included: (a) a digital record in your pocket; (b) tracking the progress of wound-healing is simple; and (c) digital apps—learning to overcome technical challenges.

A digital record in your pocket

Participants found that having a record of the wound progress and a record of communication notes from the wound specialist on their mobile device was very useful when visiting their GP or seeing other specialists. This enabled them to communicate with their additional treating clinicians on their wound progress and, at times, prevent the need to undress and re-dress the wound. Nellie, who had bilateral forefoot amputation wounds stated:

Showing the doctors, including, my specialist, the surgeon from Sydney one of the photos of what it was—where it was actually—so when I had a teleconference with him, he was able to see where it was up to.

John, age 44 who had a diabetic foot ulcer said:

And rather than undress the wound every time and then get the nurse to redress it at the GP again, I would often just pull out the app and, 'here's the photo that I took yesterday, here's the photo I took the day before' and they'd just look at the photo and go, 'yeah, that looks good.'

Tracking the progress of wound-healing is simple

The biggest benefit noted by participants was the ability to see wound progression in the images taken. The digital app arranged the images in chronological order making it easy to visualise progression and the images were not saved to the phone's photo gallery, which was important for privacy. Morris who is 64 with peripheral vascular disease reported:

And with taking photos, they're, sort of, in our photo book that we can always go back there and use them to judge how things are going and that...I'm very, very impressed with the app.

And being able to physically see—because I'm a visual person—physically see how it drilled along for a while—the healing—and suddenly it got a go on. And that gives you confidence particularly in your older years.

The digital app uses artificial intelligence to perform an analysis of the wound every time an image is taken. While this feature is particularly liked by clinicians,²⁰ the interviews showed that participants were not equally favourable to the analysis feature. Participants preferred viewing their progress through chronological sequence of images, rather than using the analysis, which generates a percentage of wound change. In Nellie's experience, the digital app:

Did width, total area and length. But these seemed to be inaccurate.

As John expressed:

...so the dot may be on an angle, where it's, oh your wound has grown and the nurse was like, no it hasn't.

And for Ben:

...a bit hard to decipher the information from the application because it tends to give you detail around the change in wound size. But it's very inconsistent.

Digital apps—learning to overcome technical challenges

Participants frequently commented how they enjoyed the digital app because of its ease of use. In some instances, participants gave their device to their community nurse or family member to take the image for them. While some participants noted they experienced some difficulties in the beginning, these were easily corrected, and they quickly became accustomed to using the digital app. For Tracy, a 49-year-old with a venous ulcer:

It was quite user-friendly, like it wasn't complex, so that was good.

Nellie, who has bilateral forefoot amputation wounds stated:

Taking the photos was easy. And the quality of the photos was really good.

And for John:

I found the app very useful. Easy to use.

Taking images using the digital app requires the participant to place a green dot near their wound and take an image planar to the sticker and wound. Some participants reported forgetting to use the green dot; others were not sure where to place it, especially for wounds on body extremities. For Ben it was:

...bit hard to use it for a wound that isn't of very flat and easy to image.

And for John it was:

...hard when [the] wound is on the toes to place the dot in a position on the same plane as the wound. This then skews the analysis.

3.4 | Wound analysis

Analysis of each wound was conducted from time of enrolment until the wound healed or until the final wound evaluation date for an unhealed wound. The

number of wounds that were completely healed within the 7-month study period was 26/61 (42.6%), with a median time to healing of 66 (95% CI: 56-88) days. Nineteen out of 26 wounds (73.1%) healed in less than 12 weeks, and all 26 wounds that healed did so within 24 weeks. The different types of wounds (as listed in Table 1) were grouped into five categories and healing outcomes for each wound category are displayed in Table 5.

Out of the remaining wounds that were still being managed by eWCC, 29 (82.9%) had improved since the time of enrolment, with a mean reduction in wound SA of 51.9% (SD 21.2%). There were 6 (17.1%) wounds, which displayed a mean increase in wound SA of 25.9% (SD 25.8%). Two of these wounds were from a patient with multiple venous ulcers, one was from a very elderly patient with deteriorating health and the other three had been monitored for less than 3 weeks.

3.5 | Potential savings due to reduced travel

This study showed that enrolment in the eWCC reduced the number of visits that a participant made to the wound specialist, but this was highly dependent on the participant's situation. For example, eight participants enrolled in the eWCC received primary care through community nursing or hospital in the home services (a clinical area to treat participants after discharge to reduce hospital length of stay),²⁷ and therefore, they did not travel to see the wound specialist. Whereas other participants did travel to see the wound specialist and these visits were modulated through the eWCC. Twenty-three

participants lived in metropolitan Sydney and visited wound specialists within metropolitan Sydney, 12 participants lived within regional/rural NSW and visited wound specialists within regional/rural NSW and 8 participants lived in regional/rural NSW but visited wound specialists in metropolitan Sydney. The travel distance, time, costs, and car pollution emissions were calculated per round trip for these participants and displayed in Figure 6.

The data demonstrated that savings for a single round trip can be experienced by all participants. Participants within metropolitan Sydney potentially saved, on average, a distance of 20.5 km (SD 16.2 km), travel time of 54 minutes (SD 25 minutes), and travel costs of \$6.37 (SD \$10.26) for a single visit. Participants that lived in regional NSW and travelled to their closest wound specialist potentially experienced travel savings of a mean of 260 km (SD 191 km), 3.1 hours (SD 2.1 hours), and \$38.02 (SD \$28.46) for a single visit. Greatest savings were experienced by those participants accessing wound specialist services remotely with a single visit potentially costing a mean of 638 km (SD 265 km) travel distance, 8.6 hours (SD 2.5 hours) travel time, and \$99.65 (SD \$42.07) fuel costs. Notably, these savings grow substantially over the course of treatment where participants can avoid numerous trips, as they remain connected to the specialised service.

In addition, the reduced travel commuted by participants equates to a reduction in CO₂ emissions into the atmosphere of up to an estimated 250 kg for a single round trip for remote participants. To put this in perspective, the average annual CO₂ emissions were estimated and compared to the number of mature trees that would need to be planted to offset this emission. From this data, around 30 to 850 trees per patient would be required to

TABLE 5 Wound-healing outcomes

Wound type	Proportion (%) healed in <12 wk	Proportion (%) healed in <24 wk	Mean (SD) wound area (cm ²)	Mean (SD) Median (IQR) healing time (d)	Mean (SD) healing rate (cm/d)
Vascular ulcers	3/19 (15.8%)	3/19 (15.8%)	7.71 (7.45)	63.7 (20.5) 62 (44–85)	0.014 (0.008)
Diabetes-related foot ulcers	8/17 (47.1%)	11/17 (64.7%)	3.81 (5.30)	69.5 (32.3) 77 (24–94)	0.011 (0.006)
Complex surgical wounds ^a	6/14 (42.9%)	10/14 (71.4%)	10.6 (13.0)	76.7 (44.1) 64.5 (33–129)	0.019 (0.013)
Pressure injuries (stage 4)	0/4 (0%)	0/4 (0%)	—	—	—
Other wounds	2/7 (28.6%)	2/7 (28.6%)	21.1 (23.3)	58.5 (5.0) 89.5 (62–117)	0.04 (0.034)

^aPostoperative, surgical dehiscence, skin graft.

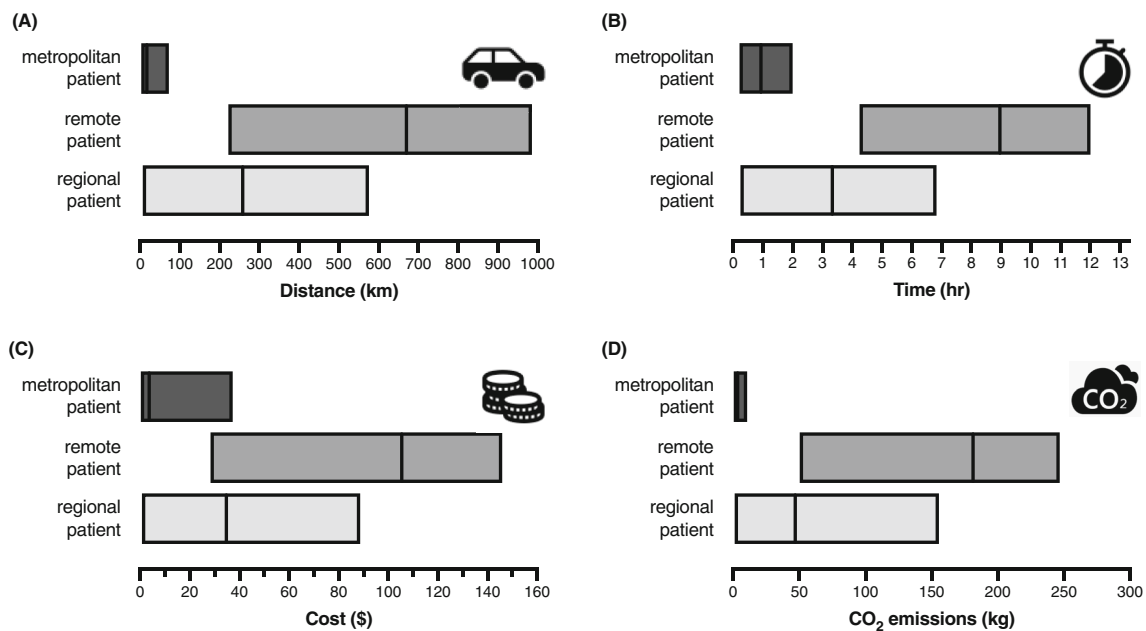


FIGURE 6 A single round trip savings for a patient in the eWCC. The figure displays minimum and maximum values with centre line at the median value for (a) distance, (b) time, (c) costs, and (d) CO₂ emissions for a single round trip to the wound specialist for participants who lived in, and accessed services in, metropolitan Sydney (metropolitan patient, dark grey), participants who lived in regional/rural NSW but accessed services in metropolitan Sydney (remote patient, medium grey), and participants who lived in and accessed services in regional/rural NSW (regional patient, light grey). eWCC, Virtual Wound Care Command Centre

be planted to offset carbon emissions by participants accessing wound services in metropolitan and regional/rural districts of NSW, respectively.

4 | DISCUSSION

Wound care in Australia is complex, compounded by a tyranny of distance within a vast geographical area, and often involves a multitude of un-coordinated health care providers with varying degrees of knowledge and skill in treating chronic wounds.³ The eWCC is a new MoC that aims to improve patient wound outcomes by providing a continuous, accessible service with ongoing remote review of chronic wounds and respective administration of wound care through a virtual setting. This study found that the eWCC enabled patients and other health professionals to work collaboratively while directly accessing centralised specialised wound consultation services remotely; thereby ensuring the patient receives best practice wound care. In addition, patients could directly access information about their wound progress via the digital app, empowering them to participate in the management of their wounds and use this tool, which was used to communicate with their local treating clinicians as needed. The model is designed to provide remote access and timely interventions for patients in the

community, administer evidenced-based treatment and preventative care, and enable continuum of care across the health services.

This study assessed the eWCC from nine centres across NSW health districts, encompassing community services, outpatient clinics, and hospital wound specialists. A pre-enrolment baseline survey showed that patients were satisfied with their wound care service provided by their wound specialist (nurse specialists, podiatrists, doctors, surgeons). A high proportion of patients perceived that wound care services through the eWCC provided improved timely access and ease of communication to their wound specialist, and increased confidence to self-manage the wound. Therefore, the eWCC was able to deliver effective remote wound services to patients without compromising on quality and patient satisfaction. Accordingly, the data demonstrated that patient safety was not diminished through remote care via the eWCC.

The use of digital technology for remote wound care is an important feature of wound care management, especially for patients that are immobile due to illness, travel constraints, or mandated lockdowns from pandemics. The platform provided by the digital app enabled participants to stay connected to wound specialist services and this was perceived as a valuable feature of the digital app, evidenced by the timely communication

responses between the participant and wound specialist. In addition, participants reported the digital app was easy to use and they benefited from being able to track their wound progress. Previous studies^{13,15,28} have reported on remote consultations through telehealth and how they were non-inferior to face-to-face consultations and provided timely assistance and diagnosis to improve management of chronic wounds.^{29,30} The eWCC goes further to provide a solution where patients can contact their wound specialist at any time and from anywhere and access a file that records the chronological progression of their wounds. In addition, the patient's primary carer can use the service to access expert advice. Recognisably, the use of video telehealth consultations can be used to complement the delivery of evidenced-based wound care practice through the eWCC.

Although the study was not designed to compare healing rates of wounds with a comparator group, it did reveal that the digital app provided a very quick and efficient way of extracting detailed wound parameters for each participant. In fact, the introduction of the digital app has enabled the accurate and comprehensive analysis of wounds,³¹ which was not possible through the eMR system used in the study setting.²⁰ Wound-healing data collected in this study was comparable to previously published data. Patients with ulcers assessed via telemedicine were reported to have a median healing time of 59 days (95% CI: 40-78) in one study²⁹ and an average healing time of 65.8 (SD 29.8) days in another.³² A study assessing chronic wounds in rural Australia over 3 years reported a mean healing time of 61.4 (SD 77.7) days.³³ Patients with a mixed aetiology of ulcers visiting an outpatient wound clinic reported 35% healing rate within 12 weeks.³⁴ Other studies have reported vascular ulcers to heal at a range of 23.5% to 45.1% within 24 weeks, a median healing time of 63.9 days⁷ and a median healing rate of 0.15 cm/wk (0.13-0.19 CI),³⁵ which was comparable to our data of 15.8% healed within 24 weeks, a median healing time of 62 days (IQR: 44-85) and a median healing rate of 0.13 cm/wk (0.034-0.23 CI). Diabetes-related foot ulcers have been reported to have a median healing time ranging from 6.0 to 15.7 weeks (42-110 days).^{7,35} Another study reported a median healing rate of all ulcers of 0.55 cm²/mo (IQR: 5.27-0.18).³⁴ Combining vascular and diabetes-related foot ulcer data from our study showed a median healing rate of 0.75 cm²/mo (IQR: 3.23-0.42). The ability to extract comprehensive wound information using the digital app will further support studies investigating new methods and products to improve healing of chronic wounds.

Translating a digital app system into an effective MoC for the remote treatment of chronic wounds is critical to service patients in rural/remote settings. In addition to providing direct access to specialist wound services,

patients can benefit from time and cost savings associated with travel. Similar to our previous study,²⁰ travel savings were achieved by participants enrolled in the eWCC and in turn, reduced carbon emissions, providing environmental benefits. In addition, the outbreak of the COVID-19 pandemic mandated physical separation between clinicians and patients and restricted travel. In these circumstances, the effective delivery of remote wound care is imperative to prevent wound deterioration. This study demonstrated that the eWCC provides an efficient and user-friendly platform that can be rapidly deployed to provide remote services to patients with chronic wounds.

The effective delivery of wound care services through the eWCC is partly dependent on patient accessibility and use of the digital app. First, in this study, it was observed that a high percentage of eligible patients were not enrolled due to either having a difficult wound location or having issues with their mobile device. Patients with a wound in a difficult location could not use the digital app to take images of their own wound. In this situation, patients may have a family member or visiting community nurse takes images, or their treating clinician can use the app to access expert advice on behalf of the patient. While the design of this study did not include studying the experience of treating clinicians in the community, future expansion of the eWCC to such clinicians will be important to improve services to patients in the community. Second, approximately one-third of patients were excluded from the study due to device issues. These patients either did not have a smart phone device or did not have an account to download digital apps. Making the digital app easily available to patients will be important for centres to deliver effective wound care and this can be achieved by offering patients a mobile device with the downloaded digital app so they could benefit from remote wound monitoring.

The study design employed to assess viability and acceptability of the eWCC meant that a comparator group was not used to compare the new eWCC MoC to standard of care. Instead, this study implemented a survey to be conducted by participants at the time of enrolment to establish baseline data of their perception towards current wound services. The same survey was used at the end of enrolment to establish their perception of the eWCC. The surveys were anonymous to minimise biasing of data. In addition, participant interviews were conducted to enrich the data from the surveys. The combined data clearly demonstrated the favourable perception that participants formed with receiving wound services through the eWCC using the digital app. Future studies can be designed with a larger cohort and comparator groups to determine if wound-healing outcomes improve and if there are any cost efficiencies to be gained

using the eWCC MoC compared to standard care. Lastly, exploring the perspective of clinicians on the eWCC would give insights into receptiveness, uptake, barriers, and facilitators for future scale up for different specialists and settings.

In conclusion, individuals with chronic wounds receiving remote wound care services through the eWCC using the digital app experienced improved timely access to wound care services, ease of communication with their wound specialist, and self-empowerment to manage their wounds. Remote monitoring of wounds did not decrease the quality of care or increase risk to the patient. Patients valued the direct connectivity afforded by the digital app to their wound specialist for continued wound care and confidence in wound management. In addition, most patients found the digital app easy to use, suggesting the use of new digital technology was acceptable among an older generation that is prone to chronic wounds. Collectively, the study provides a valuable analysis of the eWCC, demonstrating its viability and acceptability for providing virtual wound care services while maintaining quality and patient experience. This supports the continued expansion of this work across the health network.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from [third party]. Restrictions apply to the availability of these data, which were used under license for

this study. Data are available [from the authors / at URL] with the permission of [third party].

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