

Use of photograph-based telemedicine in postoperative wound assessment to diagnose or exclude surgical site infection

Objective: This study aims to assess whether a clinician reviewing photographs of a wound was an acceptable substitute for clinical review in order to identify or exclude surgical site infection (SSI).

Method: We undertook a mixed methods study consisting of a qualitative public involvement exercise and a prospective, non-randomised, single-centre study of patients undergoing clean or clean-contaminated vascular surgery. For the qualitative study, two semi-structured focus group interviews were conducted. For the prospective study, patients were invited to attend a wound review at 5–7 days and 30 days postoperatively. At review, wounds were scored by a study nurse or doctor, according to the ASEPSIS scale. Anonymised wound photographs were taken and independently reviewed, and ASEPSIS scored by two independent investigators blinded to the original 'clinical review' ASEPSIS score.

Results: In the qualitative study, three female patients were interviewed across two dates. Emerging themes included the burden of SSI, hospital follow-up and telemedical follow-up. A total of 37 patients

with a mean age of 61.14 years were included in the quantitative analysis. There was a total of 53 wound reviews. There was >85% agreement between photograph and clinical reviewers in all categories except erythema. The specificity of photograph review for diagnosis of SSI was 90%. The intraclass correlation coefficient for total ASEPSIS score was $R=0.806$ (95% CI 0.694, 0.881), indicating strong reliability between reviewers.

Conclusion: Our data shows that, in the assessment of SSI, there is good correlation between face-to-face clinical and remote photographic review. Incorporating this method of wound assessment into a postoperative follow-up care pathway may save patients and clinicians from unnecessary hospital visits, particularly when conducting health research.

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clinical trials • public involvement • surgical site infection • telemedicine

Surgical site infection (SSI) has a reported incidence of between 1% and 9.2% in England, rising to 25% in some studies,^{1,2} and is a significant cause of morbidity and mortality. Consequences of SSI may include prolongation of hospital admission or readmission to hospital, sepsis, a return to the operating theatre, amputation, and even death.^{3,4} The early identification of SSI is important as early infections can often be managed on an outpatient basis with oral antibiotics rather than requiring readmission to hospital for intravenous treatment, more complex dressing management or surgical debridement.

Typically, following discharge from hospital, identification of infection requires clinical review, either by the patient's primary physician, practice or community nurse, or as a hospital outpatient. This could be burdensome to the patient, who may require

additional mobility aids, hospital transport, and friends or family support to attend appointments. There is an associated cost to both the patient, in the form of opportunity and financial costs, and to the health-care provider, in terms of the financial burden of clinician time and further treatment. Although some health professionals now employ telephone consultations as routine practice, these lack the ability to make an objective assessment, and clinicians must rely upon the information provided by the patient.

In the digital age, clinicians are increasingly turning towards technology to aid patient assessment in a timely and safe manner.⁵ Telemedicine has been proposed as a potential solution,⁶ and in a 2010 systematic review the technology was rated as 'good' by 20 studies, and 'promising' by a further 19 studies.⁷ As 81% of UK adults own a smartphone,⁸ clinicians could use this technology in both routine practice and clinical trials to improve diagnosis and study retention rates and reduce the cost of follow-up.

Aim

This study had three primary aims:

- To assess the sensitivity and specificity of wound photographs in diagnosis of superficial SSI
- To assess the levels of agreement between clinical

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observers and independent observers of wound photographs

- To investigate the acceptability to patients of telemedicine-based clinical follow-up.

Methods

Study design

The study was a mixed methods study consisting of a prospective, non-randomised, single-centre study, taking place between January and May 2017. The study was carried out within a tertiary vascular surgery service at a university teaching hospital, and a public involvement (PI) consultation exercise took place in April 2017 in the same centre. The study was approved by a research ethics committee (16/LO/2135) and all patients provided written and informed consent before inclusion in line with the Declaration of Helsinki (1974).

Inclusion criteria for the prospective study were patients over the age of 18 years and undergoing clean or clean-contaminated vascular surgery. Inclusion criteria for the PI exercise were patients who had been diagnosed with SSI in a three-month period leading up to invitation to take part in the study. No specific exclusion criteria was set for the public involvement exercise. For the prospective part of the study, patients undergoing carotid endarterectomy, and patients who were unable to give consent due to incapacity (as defined by the Mental Capacity Act 2005)⁹ were excluded from the study.

Public involvement exercise

The PI exercise consisted of two semi-structured focus group interviews, each lasting approximately 90 minutes. Interviews were conducted using a topic guide, however, a flexible format was used to allow patients to express thoughts and opinions freely. Topics included SSI, wound dressings and research procedures. Eligible patients were identified through the vascular ward discharge register and through the vascular surgery consultants. They were invited to participate by letter, and sent an information sheet to read, followed by a telephone call to discuss the study further and confirm participation. The exercise took place in a hospital setting that was comfortable and accessible. All interviews were audio recorded, with the consent of participants, and transcribed verbatim.

Public involvement exercise: statistical analysis

Data was managed using a qualitative computer software package (NVIVO, QSR International). Analysis involved a process of transcription, organisation into categories (dressings, follow-up, infection, photographs, travel distance and trial procedures), writing and theorising.

Prospective study: postoperative follow-up

On postoperative day 5–7, and postoperative day 30(±3 days), patients were invited for clinical review. These intervals were chosen as a result of a previous

pilot study into SSI undertaken in the same centre.¹⁰ Wound assessment was undertaken by a research nurse or doctor, and wounds scored on a modified ASEPSIS scale,¹¹ aimed at objectively scoring wounds for SSI. Wounds were scored for:

- Erythema (defined as any redness around the wound area)—3 points
 - Serous exudate—3 points
 - Purulent exudate—6 points
 - Wound edge separation—6 points.
- When the ASEPSIS scale was used to diagnose infection in clinical practice, further marks were given for:
- Antibiotic prescription—10 points
 - Abscess drainage 5 points
 - Wound debridement—10 points
 - Isolation of bacteria —10 points
 - Prolonged stay or readmission to hospital—5 points.
- A score of ≥21 was diagnostic of SSI.

Prospective study: photograph procedures and assessment

After clinical review, anonymous digital photographs were taken of the patients' wounds by a different researcher using the same 16.1 megapixel compact digital camera (Nikon Coolpix L31). There was no standardisation of flash, focus or distance from wound. Single or multiple frontal photographs were taken of each wound, at the discretion of the photographer, to allow close-up viewing of the wound. Photographers ensured that the whole wound was seen in either a single photograph, or between the photographs taken, and used the camera viewing screen to identify whether the sharpness of the image was sufficient to be used. No lateral views were taken. The digital photograph images were uploaded to a secure hospital server and reviewed separately by two independent doctors (Reviewers PR1 and PR2). Reviews were completed using standard definition LCD computer display screens. Review doctors were not involved in routine clinical follow-up of participants in the study, and had not seen any of the wounds before reviewing the photographs. Reviewers scored the wounds according to the modified ASEPSIS scale, set out above.

In addition to scoring the wounds, the two clinicians assessing photographs were asked to state whether they would like to review the patient in person to fully assess their clinical condition, if they suspected superficial SSI.

Prospective study: statistical analysis

Data was collected using a purpose-designed Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, Washington). Statistical analysis was performed using IBM SPSS 23 (IBM Corp, Armonk, New York).

Inter-observer agreement

Percentage agreement values and Cohen's Kappa¹² values were calculated to assess for inter-rater reliability between the in-room reviewer and each photograph reviewer, and between the two photograph reviewers

(PR1 and PR2). As the photograph reviewers in this study were blinded to patient outcome, correlation values were calculated by using only the subjective wound appearance scores from the ASEPSIS tool.

Sensitivity and specificity

To calculate sensitivity and specificity values, it was assumed that when reviewing photographs, asking for a further review of the patient constituted diagnosis of an infection. The 'gold standard' of diagnosis at clinical review was either total ASEPSIS score ≥ 21 (as outlined above), or prior diagnosis of infection by the attending physician, taken from the patient's clinical notes, as defined by the Centres for Disease Control and Prevention (CDC).^{13,14}

Results

Public involvement exercise

A total of nine patients were invited to take part in the exercise. From this group, three female participants were recruited and attended both sessions (the other six patients either declined to take part or were unable to attend both sessions). The mean age of participants was 70 years (range: 61–79 years). Several themes emerged during analysis of the data, including SSI, hospital follow-up and the use of telemedicine.

Surgical site infection: pre-procedure awareness

All three patients acknowledged that infection had been mentioned to them as a consequence of undergoing an operative procedure. When asked, one patient explicitly stated that she did not consider it important before the operation:

Reviewer: *'Did you feel that it was important before your operation, or did you consider it as important before your operation?'*

Patient: *'No, I didn't.'* (patient 3)

Physical and non-physical consequences of infection

All three patients spoke at length about the consequences of infection, both physical:

'I don't walk far.' (patient 3)

'Getting in and out of the car still is a problem'
(patient 3)

As well as non-physical:

'Emotionally it's been a nightmare, and if go out and about with anyone they have to realise that I do have to stop every so often.' (Patient 2)

Most patients described an impact on daily activities such as being unable to shop, walk or, at times, dress themselves:

'I struggle to get dressed, trousers and underwear especially.' (patient 2)

Contact with health professionals and hospital stay

Multiple contacts with health professionals was a recurring theme during the course of a SSI. In general, patients were attended to by a GP, a practice nurse, district nurses and their hospital consultant before readmission to hospital. A patient also attended their local accident and emergency department. The average length of readmission was 13 days (range: 9–17 days), which had a significant impact on the patient:

'[I was] devastated. Absolutely devastated.' (patient 2)

Even after discharge, patients continued to be dependent on healthcare services, requiring daily or alternate daily dressings from community care teams.

Antibiotic therapy

Patients described antibiotic therapy as 'horrendous,' 'really, really bad' and 'awful'. Common concerns included intravenous (IV) access for antibiotic therapy with one patient stating in reference to IV cannulation:

'I could cry even thinking about it.' (patient 2)

Hospital follow-up shortly after an operation

Patients felt that follow-up shortly (seven days) after an operation would be problematic, particularly in the context of a clinical research trial:

'I don't think I'd have managed it' (patient 2)

'I don't think you're feeling well enough to do that.'
(patient 2)

Attending hospital

Patients found that attending hospital was a particular problem at any time—one patient lived 34 miles away from hospital—citing an inability to drive after an operation:

'I'd have to get somebody to bring me.' (patient 3)

Issues around 'no parking', and problems with traffic:

'To get here for two today, I left at one. If I do it at midnight it's 15 minutes.' (patient 1)

Telemedicine follow-up: home visits and

follow-up conducted by postal questionnaire only

Patients had mixed feelings about home visits, with one patient stating it:

'Wouldn't bother me and I live on my own.' (patient 1)

But others expressed that patients may find it 'intrusive':

'I do think a lot of people, these days especially, don't like people coming in in their homes.' (patient 2)

Table 1. Demographic data for prospective study

Age, years (range)	61.14 (38–83)
Male (n)	23
Female (n)	14
Surgery type	
Abdominal aorta	9
Open lower limb arterial surgery	12
Open varicose vein surgery	3
Major lower limb amputation	6
Dialysis access formation	3
Other	4
Diabetes	
Diet controlled	2
Tablet controlled	4
Insulin controlled	4
Smoking status	
Current smoker	6
Ex-smoker	22

When asked about postal questionnaires only, one patient expressed that this would be ‘bad’, and that they would:

‘Feel like you were just drawing a line under me.’
(patient 2)

Photographing wounds

In general, patients found the idea of photographing their wounds acceptable:

‘It wouldn’t bother me having photographs taken.’
(patient 2)

All patients felt they were either technically ‘savvy’ enough to photograph their own wound and send it to doctors:

‘Oh yes I could do that, I send photographs of my garden.’ (patient 1)

Or could find assistance in doing so:

‘I’d get my son to take them.’ (patient 3)

No patients expressed concerns over the anonymity of photographs:

‘Take a photograph of my leg it could be anyone’s leg.’
(patient 3)

Or the sharing of photographs between patients and doctors or between health professionals using secure servers:

‘If your name isn’t on it, it doesn’t matter, they’ve got far more interesting photographs on the internet.’
(patient 1)

Telemedicine using a photograph and a phonecall

Patients in general felt that enough information could be gathered over the telephone to assess their current health:

‘if you asked the right questions’ (Patient 3).

Patients did express that they felt reassured by seeing a doctor or a nurse in person for follow-up:

‘I think you need the reassurance as well and you just need to know its doing okay,’ (patient 1)

But when asked about using a photograph to show their wound to a doctor on the other end of a telephone, all patients were in agreement that this offered them the same reassurance:

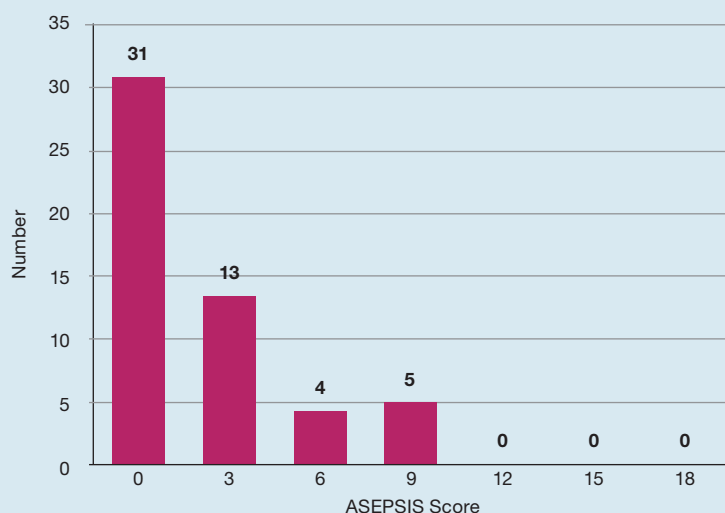
‘Yeah, plus the photograph as well, helps if you thought there was something suspicious then you could pick up on that.’ (patient 2)

Prospective Study

For the prospective study, 37 patients, 23 male and 14 female, with a mean age of 61.14 years (range: 38–83 years) had a total of 53 photographs taken of their surgical wound sites, and compared with the assessment made at the prior formal clinical review. Of the 53 photographs, 30 were taken at the 5–7 day follow-up appointment. Table 1 illustrates demographic data for the patient cohort.

The total available ASEPSIS Score to be compared using correlation statistics was 18. The overall spread of this score for conventional clinical review is shown in Fig 1.

Fig 1. Spread of overall ASEPSIS score at conventional clinical review



Inter-observer agreement

For the presence or absence of erythema, serous exudate, purulent exudate or wound edge separation, percentage agreement values are shown in Table 2.

The two photograph reviewers had >85% agreement with each other in all four categories, and >85% agreement independently with the clinical reviewer in all categories except erythema. For Kappa values, a value of 0.21–0.40 was taken to indicate a fair agreement, 0.41–0.60 a moderate agreement, 0.61–0.80 a substantial agreement and 0.80–1.00 an almost perfect agreement.¹⁵ Agreement between the photograph reviewers was statistically significant for all four ASEPSIS categories, reaching substantial or almost perfect agreement for erythema and purulent exudate (Table 3). Agreement between the clinical and photograph reviewers was more variable. Agreement between the clinical reviewer and first photograph reviewer reached statistical significance in two of the four ASEPSIS categories (purulent exudate and separation of wound edges). Agreement between the clinical reviewer and second photograph reviewer reached statistical significance in three of the four ASEPSIS categories (erythema, serous exudate and purulent exudate).

From the ASEPSIS tool used in this study, only erythema showed a weak correlation between assessors, with Cohen's Kappa value of 0.308 and 0.053 respectively. Of the wounds, 18 were identified as erythematous in person, with 13 and 16 identified as erythematous by reviewers PR1 and PR2 respectively.

A two-way random model, intraclass correlation coefficient for absolute agreement between all three reviewers for the total ASEPSIS score (maximum: 18) was 0.806 [95% Confidence Interval (CI) 0.694, 0.881], indicating good reliability between reviewers.¹⁶

There was an almost perfect agreement between the independent photograph reviewers' responses ($\kappa=0.912$, $p<0.01$) in terms of asking to review patients in person.

Sensitivity and specificity

Assuming that a photographic reviewer asking for a conventional clinical review constitutes diagnosing an infection, sensitivity and specificity values were calculated for each reviewer based upon patients who were diagnosed as having had an SSI in the follow-up period (Table 4). The specificity of this method of wound review for diagnosing infection was found to be 90%.

Discussion

Telemedicine is a rapidly expanding area of modern medicine. Studies have shown that telemedicine consultations are acceptable to patients¹⁷ and increasing in prevalence and significance,¹⁸ and so should be considered as a viable method of conducting health research and clinical follow-up.

Early identification of SSI may avoid the significant impact to patients that was described during the PI

Table 2. Inter-rater reliability as shown by percentage agreement values

ASEPSIS score category	Inter-reviewer agreement, n, (%) [*]		
	A	B	C
	CR versus PR1	CR versus PR2	PR1 versus PR2
Erythema	32/53 (60.4)	37/53 (69.8)	46/53 (86.8)
Serous exudate	49/53 (92.5)	48/53 (90.6)	48/53 (90.6)
Purulent exudate	52/53 (98.1)	52/53 (98.1)	53/53 (100)
Separation of wound edges	47/53 (88.7)	44/53 (83)	50/53 (94.3)

^{*}n—number of times agreement was reached; values in brackets represent percentage agreement^{*}; A—agreement between clinical reviewer (CR) and photograph reviewer 1 (PR1); B—agreement between CR and photograph reviewer 2 (PR2); C—agreement between photograph reviewers

Table 3. Inter-rater reliability as shown by Cohen's Kappa values

ASEPSIS score category	Inter-reviewer agreement (Kappa) [*]		
	A	B	C
	CR versus PR1	CR versus PR2	PR1 versus PR2
Erythema	0.053 (0.693)	0.308 (0.02)	0.669 (<0.01)
Serous exudate	0.298 (0.21)	0.245 (<0.05)	0.394 (<0.01)
Purulent exudate	0.658 (<0.01)	0.658 (<0.01)	1 (<0.001)
Separation of wound edges	0.444 (<0.01)	0.035 (0.67)	0.381 (<0.01)

Values in brackets represent p-values; items in bold represent statistically significant p values ($p<0.05$); A—agreement between clinical reviewer (CR) and photograph reviewer 1 (PR1); B—agreement between CR and photograph reviewer 2 (PR2); C—agreement between photograph reviewers

Table 4. Sensitivity and specificity values

Reviewer	Sensitivity	Specificity
PR1	50%	90%
PR2	100%	90%
Mean	75%	90%

exercise as part of this study, including readmission to hospital and prolonged treatment with antibiotics. This impact reflects that experienced by other patients having undergone colorectal surgery,¹⁹ who found infections 'devastating.' The experience of the patients in our study outlines not only the cost to patients but also the burden on health-care systems, with each patient suffering SSI requiring multiple contacts with health professionals before, during and after their treatment.

We demonstrated good correlation between a face-to-face clinical review and a photograph review of a wound, when screening for SSI using a validated, objective scoring system (Table 2 and 3), and a high specificity for diagnosing infection (Table 3). We propose a method of wound infection screening where photography is used to assess the appearance of a wound (erythema, serous exudate, purulent exudate

and wound edge separation), with a telephone call and access to clinical records used to assess for other aspects of the ASEPIS score (antibiotic prescription, abscess drainage, wound debridement, isolation of bacteria and prolonged stay or readmission to hospital). Wounds without complications would not require the patient to attend hospital. Early work has shown telephone follow-up to be reliable in screening for problems with wounds.^{20,21} Of the 53 wound reviews that took place in this study, 46 could have been conducted using this method of follow-up, avoiding a hospital visit in 86.7% of cases. Therefore, digital photography may be a useful tool where patients are unable or unwilling to attend in person for further clinical follow-up. This is particularly important with the increase in centralised hospital services; distance from hospital is directly associated with failure to attend clinic follow-up,²² and in specialties that run a 'hub and spoke' model, often covering a very large geographical area, any strategies aimed at reducing the travel burden to patients and reducing loss-to-follow-up should be explored.

The patients in this PI study identified problems with travel, hospital parking, and the short nature of hospital visits as barriers to hospital-based follow-up. When presented with the idea of taking photographs of their wound to send to study doctors, in conjunction with a short telephone consultation, all participants were in favour of this idea. The results of this study are supported by other studies examining telemedicine in vascular surgery,²³ cardiology²⁴ and plastic surgery.^{25,26}

This study supports a postoperative follow-up care pathway whereby the clinician uses a remote photograph and telephone interview with the patient to assess the necessity/requirement for formal, face-to-face, clinical review. This model provides a 'safety-net' for both the patient and clinician, and was acceptable when suggested to the PI focus group. It offers the possibility of patient-led wound monitoring, where the patient is able to contact the medical team with a photograph if they feel their wound has deteriorated and warrants clinical review. In the context of clinical trials, this makes their involvement in research more patient-centred, which may improve study retention rates.

The under reporting of erythema may demonstrate a reduced visibility of colour when reviewing wound

photographs, or may be a result of the lack of standardisation of flash between images. Skin reflection where flash is used may reduce the visibility of erythema in images, and future research trials, or indeed use of this method in clinical practice should aim to at least standardise flash in images, even if aspects such as distance from the wound are left to the discretion of the photographer.

Other domains of assessment showed good agreement. For example, percentage agreement in serous exudate was consistently >90%, although this was associated with a relatively low kappa value. Only two wounds were assessed as having serous exudate in person—a larger study may be necessary to validate the results that this study has produced.

Limitations

This study has certain limitations that should be considered. Firstly, the sensitivity of photography for diagnosing infection is difficult to interpret as relatively few patients (two) developed SSI. However, we can say with more certainty that photography has high specificity, and if used as a triage tool could be effective at identifying wounds at very low risk of infection and not requiring clinical review. Secondly, the photographs used in this study were taken in clinic, by a study doctor with a dedicated camera. Further research should firstly aim to replicate these results on a larger scale, but with photographs taken by patients or their carers using easily accessible smartphone cameras. This may lead to large-scale research trials in which models of telemedical follow-up are cross-examined for safety, efficacy and cost-effectiveness. Finally, the PI consultation exercise was small, and a larger activity with more participants could add to this work to create more robust qualitative research.

Conclusion

In conclusion, we have shown that, in the assessment of SSI, there is good correlation between face-to-face clinical and remote photographic review, and that this approach appears to be acceptable to patients. Incorporating this method of wound assessment into a postoperative follow-up care pathway may save patients and clinicians from unnecessary hospital visits, particularly when conducting health research. **JWC**

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Reflective questions

- What criteria for assessing patients for surgical site infection (SSI) can be used when reviewing patients in person?
- What ethical issues might arise as clinicians use photographs in practice? For example, what should be considered when sending or showing a photo of a wound to another clinician?
- What are the potential risk factors for SSI in vascular surgical patients?

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Specialist wound care to help rebuild the lives of those injured in conflict

Woundcare4Heroes was launched to develop a national network of complex wound management services. These services assist the NHS in providing lifelong support and care for those discharged from the Armed Forces. Improvised explosive devices (IEDs) are designed to inflict catastrophic wounds, causing horrific, life-changing injuries, which require long-term, complex wound care.

Woundcare4Heroes aims to provide injured service personnel with access to specialist wound healing services near to their home. This enables family and friends to support them through these life-changing circumstances, with the potential to dramatically improve their wound healing and, as a result, their life.

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