

Use of Telemedicine for Postdischarge Assessment of the Surgical Wound

International Cohort Study, and Systematic Review With Meta-analysis

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Objective: This study aimed to determine whether remote wound reviews using telemedicine can be safely upscaled, and if standardized assessment tools are needed.

Background: Surgical site infection (SSI) is the most common complication of surgery worldwide, and frequently occurs after hospital discharge. Evidence to support implementation of telemedicine during postoperative recovery will be an essential component of pandemic recovery.

Methods: The primary outcome of this study was SSI reported up to 30 days after surgery (SSI), comparing rates reported using telemedicine (telephone and/or video assessment) to those with in-person review. The first part of this study analyzed primary data from an international cohort study of adult patients undergoing abdominal surgery who were discharged from hospital before 30 days after surgery. The second part combined this data with the results of a systematic review to perform a meta-analysis of all available data conducted in accordance with PRIMSA guidelines (PROSPERO:192596).

Results: The cohort study included 15,358 patients from 66 countries (8069 high, 4448 middle, 1744 low income). Of these, 6907 (45.0%) were followed up using telemedicine. The SSI rate reported using telemedicine was slightly lower than with in-person follow-up (13.4% vs 11.1%, $P < 0.001$), which persisted after risk adjustment in a mixed-effects model (adjusted odds ratio: 0.73, 95% confidence interval: 0.63–0.84, $P < 0.001$). This association was consistent across sensitivity and subgroup analyses, including a propensity-score matched model. In 9 eligible nonrandomized studies identified, a pooled mean of 64% of patients underwent telemedicine follow-up. Upon meta-analysis, the SSI rate reported was lower with telemedicine (odds ratio: 0.67, 0.47–0.94) than in-person (reference) follow-up ($I^2 = 0.45$, $P = 0.12$), although there a high risk of bias in included studies.

Conclusions: Use of telemedicine to assess the surgical wound post-discharge is feasible, but risks underreporting of SSI. Standardized tools

for remote assessment of SSI must be evaluated and adopted as telemedicine is upscaled globally.

Keywords: surgical site infection, surgical complications, global surgery, global health, research methodology, outcome assessment

(*Ann Surg* 2023;277:e1331–e1347)

Telemedicine has now become a core component of health service delivery. During COVID-19 outbreaks, patients have been encouraged not to return to hospital for in-person assessment after surgery due to fear of SARS-CoV-2 transmission.^{1–4} Use of telemedicine in surgical follow-up has rapidly increased, but without opportunity for detailed evaluation.^{5–7} If telemedicine assessment is not standardized it risks underreporting or misidentification of complications, and harm for patients. Better understanding the capacity to deliver telemedicine in the surgical setting and the accuracy of remote assessment for common complications will be fundamental to the pandemic recovery effort.^{8,9} This may be particularly important in low-resource settings where, even pre-pandemic, patients had to travel longer distances to hospital and risk catastrophic expenditure as a result of a surgical episode.¹⁰

Surgical site infection (SSI) is the most common complication of surgery, with a high burden of morbidity, detriment to quality of life and economic consequences for both patients and providers.^{11–14} It has global impact with variation in risk across settings.¹⁵ SSI often presents after patients' have left hospital after surgery.¹⁶ The current accepted standard in SSI assessment requires an in-person review by an appropriately trained clinician, according to US Centre for Disease Control Criteria (CDC).¹⁷ In accordance with this framework, patients must travel back to hospital as an outpatient, or for a clinician to visit them in the community. While telemedicine is an attractive target for assessment of the surgical wound, the evidence for its adoption remains limited. Quality of wound assessment is proportionate to the reported rate of SSI.^{18,19} Even in randomized trials, where SSI is a secondary rather than primary outcome the reported rate of SSI is twice as low.¹⁸ Unstandardized telemedicine assessment therefore risks delay to timely intervention and introduction of research bias.^{20,21}

The aims of this cohort study, and systematic review with meta-analysis were to whether telemedicine wound assessment in feasible across different settings, and to compare the rates of SSI reported using telemedicine and in-person follow-up.

METHODS

Part 1. Cohort Study

This was a preplanned, secondary analysis of a prospective, international, multicenter cohort study conducted across the GlobalSurg Collaborative network (GlobalSurg-2).²² Detailed

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This report was funded by a DFID-MRC-Wellcome Trust Joint Global Health Trial Development Grant (MR/N022114/1) and National Institute for Health Research (NIHR) Global Health Research Unit Grant (NIHR 16.136.79). The lead author (J.G.) is supported by an NIHR Doctoral Research Fellowship (DRF/100375). The funder had no role in study design, data collection, analysis and interpretation, or writing of this report. The funder has approved the submission of this report for publication. The views expressed are those of the authors and not necessarily those of the National Health Service, the NIHR, or the UK Department of Health and Social Care.

The authors report no conflicts of interest.

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.annalsofsurgery.com.

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DOI: 10.1097/SLA.0000000000005506

methodology for the study has been previously published.¹⁵ Each contributing institution sought and obtained ethical and institutional approval according to local regulations. This study was registered with ClinicalTrials.gov (NCT02662231).

Inclusion and Exclusion Criteria

Any center performing elective and/or emergency abdominal surgery was invited to participate. Local investigators used consecutive sampling to include all patients undergoing elective (planned) or emergency (unplanned) gastrointestinal resection within discrete 2-week periods. Both open and minimally invasive approaches were eligible. Both adults and children (of any age) were eligible for inclusion. Patients were excluded where the primary identification for surgery was vascular, gynecological, obstetric, urological, or for transplantation.

Data Variables and Data Collection

Data were collected using a secure, password-encrypted, web-hosted Research Electronic Data Capture (REDCap) system. Participating centres were grouped into tertiles according to the United Nation's Human Development Index (HDI). A full description of the data variables collected is available in the primary report of this study.¹⁵ Data variables were chosen pragmatically to be objective, easily standardized and internationally relevant to minimize missing data and maximize data quality. Independent data validation was performed for case ascertainment and data accuracy.

Classification of Follow-up Method

Investigators were asked to actively monitor patients up to 30-day after surgery, and performed an assessment for SSI at 30-days after surgery by 1 of 3 methods: (1) telemedicine review (telephone and/or video assessment), which was not standardized in the study, but was performed according to local practice and informed by CDC criteria; (2) in-person clinical review, either during an outpatient clinic appointment or a community visit in accordance with CDC criteria; (3) inpatient only, with in-hospital assessment and review of patient notes and electronic records up to 30 days after surgery (ie, no contact made after discharge). Patients that remained an inpatient at 30 days postoperatively were excluded from analysis (including those that were readmitted and were in hospital at 30 days after surgery). Patients that were readmitted and discharged before 30 days after surgery had an independent 30-day assessment of their SSI status.

Outcome Measures

The primary outcome measure was SSI reported up to 30 days after surgery defined according to the US Centre for Disease Control criteria.¹⁴ We included both superficial and deep infections but excluded organ space infection, which has a different biological mechanism (eg, anastomotic leak, gross contamination). Training in the CDC criteria for SSI diagnosis was provided to all investigators using an online training module. The secondary outcome measure was 30-day postoperative mortality rate with day 0 as the day of surgery.

Statistical Analysis

Differences in characteristics and the reported rates of SSI between telemedicine, in-person and inpatient only follow-up were tested with the Pearson χ^2 test for categorical variables and with the Kruskal-Wallis test for continuous variables. There is likely to be variation in the methods of adoption of telemedicine

across different resource settings. Global variation was explored by stratifying comparisons between high-HDI, middle-HDI and low-HDI countries to explore whether patterns were consistent across health systems. Multilevel logistic regression models were constructed to explore associations between the method of follow-up and the SSI rate reported. Characteristics and outcomes of patients with no postdischarge assessment (inpatient only) were described for transparency, but were excluded from multivariable modelling. Adjustment for case mix was performed using patient, disease and operation-specific factors, informed by a causal model constructed to inform covariable selection and presented using a directed acyclic graph (DAG). Country was incorporated as random effects with a constrained gradient. Discrimination of the model was determined using the *c*-statistic (area under the receiver operating curve characteristic). Model coefficients were presented as adjusted odds ratios (OR) with 95% confidence intervals (CI). To account for death after surgery as a competing risk, patients who died before 30-day follow-up were excluded in a sensitivity analysis of the primary analysis. A second sensitivity analysis was conducted including only patients with a postoperative length of stay of 14 days or less. A third sensitivity analysis included elective cancer surgery only. The final sensitivity analysis was performed in propensity score matched groups to address a risk of selection bias and counterfactuals^{23,24} (full methodology in *Appendix A*). Subgroup analyses were performed for the primary analysis across high versus middle or low HDI countries. To explore risk of reverse causation (ie, patients with serious postoperative complications seeking in-person review) we looked for associations between follow-up method and 30-day postoperative mortality rate. All analyses were done using the R Foundation Statistical Program version 4.1.1 (Auckland, New Zealand) (packages: finalfit, tidyverse, boot, MatchIt, cem, randomForests).

Part 2. Systematic Review and Meta-analysis

A systematic database search was performed according to a prepublished protocol (PROSPERO:192596) and followed Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidance. Studies reporting SSI rates detected using telemedicine and in-person assessment after noncardiac surgery were included. Data extracted from published studies was combined with cohort data and a meta-analysis performed with all available data.

Database Search and Report Characteristics

A search strategy was constructed using Medline, EMBASE, and PubMed to identify 2 key concepts within published literature: (1) SSI and (2) telemedicine. The full search strategy for the review is available in the *Appendix B*. All included studies assessed a proportion of patients both by telemedicine and in-person follow-up. The full inclusion and exclusion criteria are reported in *Appendix C*.

Outcome Measures

The primary outcome measure was the rate of SSI reported up to 30 days after surgery in the study. In the meta-analysis, this was defined pragmatically according to any classification system adopted (US CDC, ASEPIS or Public Health England), or diagnosis by a clinician. The secondary outcome measure was the proportion of patients undergoing telemedicine versus in-person follow-up.

Data Extraction and Analysis

Full texts were retrieved for all studies that potentially met the inclusion criteria. Any disagreement on eligibility of studies was resolved through consensus discussion with a third reviewer. Data on the proportion of patients with an SSI reported by telemedicine and by in-person follow-up, and the proportion of patients that underwent telemedicine follow-up were extracted from eligible study, and combined with data from the cohort study in *Part I*. Data extraction was performed and cross-checked for accuracy by 2 reviewers.

Data analysis was performed using R Foundation Statistical Program version 3.1 (packages: meta, metabin). Outcome measures were quantitatively summarized where data were available. Firstly, meta-analysis performed to estimate the pooled mean proportions of patients followed-up using telemedicine. Secondly,

meta-analysis was performed to compare the reported SSI rates with telemedicine and in-person follow-up. Heterogeneity among study estimates was quantified using the I^2 and an associated test for heterogeneity. As heterogeneity was likely to be high, the DerSimonian and Laird random effects (RE) method was used to pool estimates, with inverse-variance weights. A subgroup analysis was performed of data from high versus low and middle-income countries (packages: metaprop, meta).

Risk of Bias Assessment

Risk of bias was assessed for nonrandomized studies using the ROBINS-I tool. As this was not a clinical effectiveness study, a GRADE level of evidence assessment was not deemed to be required.

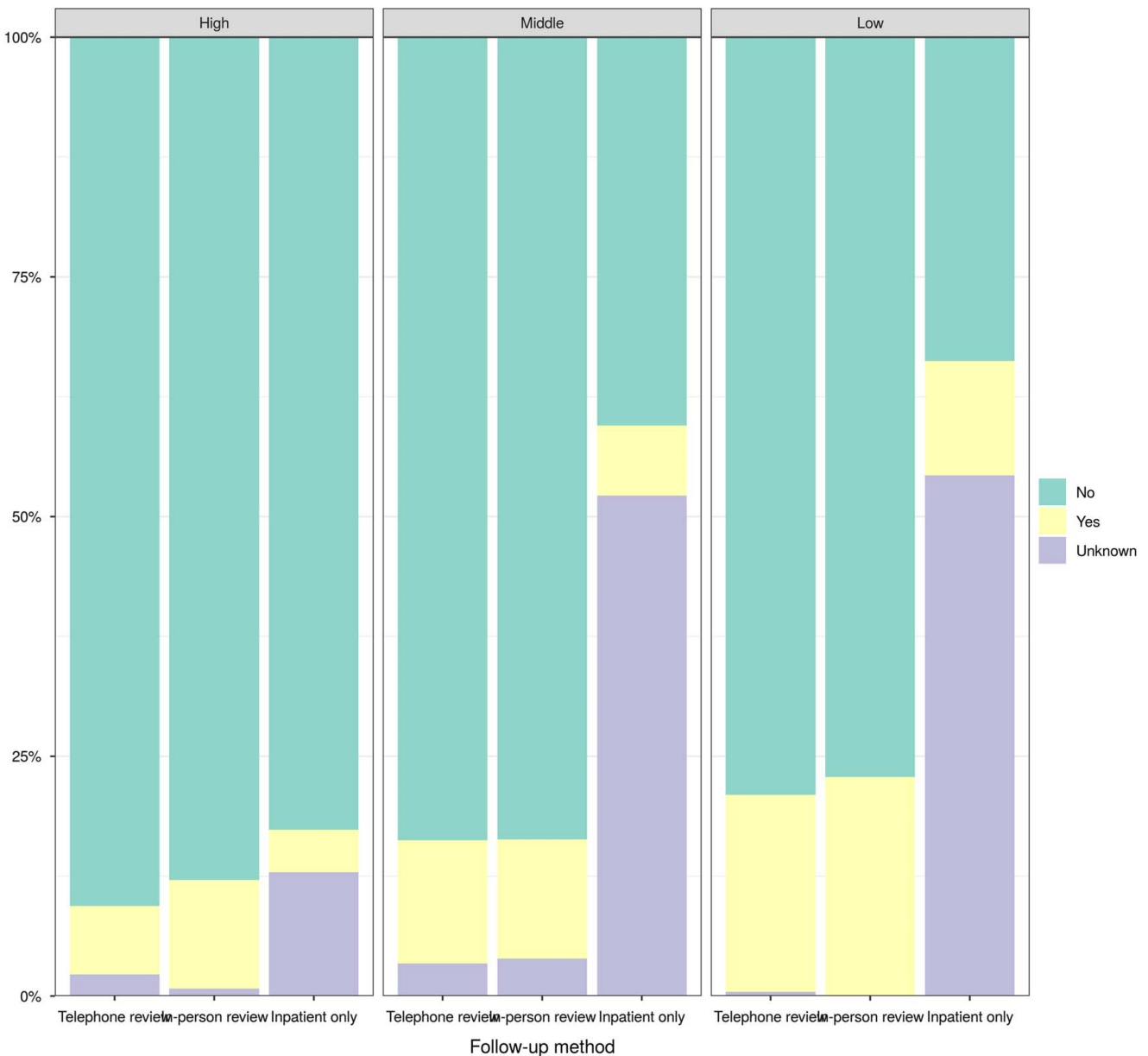


FIGURE 1. Surgical site infection rates by method of follow-up across high-income, middle-income and low-income settings.

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TABLE 1. Patient, Disease and Operation-specific Factors Grouped by Follow-up Strategy

Factor	Levels	Telemedicine	In-person Review	Inpatient Only	P
Total		6479 (44.6)	5847 (40.2)	2206 (15.2)	—
HDI tertile	High	3113 (36.7)	3823 (45.0)	1556 (18.3)	< 0.001
	Middle	3075 (61.4)	1358 (27.1)	573 (11.4)	
	Low	719 (38.7)	990 (53.2)	151 (8.1)	
Age group	<20	1003 (46.6)	823 (38.2)	326 (15.1)	< 0.001
	20–39	2332 (47.9)	1737 (35.7)	802 (16.5)	
	40–59	1967 (45.9)	1710 (39.9)	608 (14.2)	
	60–79	1312 (40.5)	1482 (45.8)	444 (13.7)	
	80–100	154 (31.8)	261 (53.8)	70 (14.4)	
Sex	Male	2865 (41.8)	2991 (43.7)	995 (14.5)	< 0.001
	Female	3614 (47.1)	2856 (37.2)	1211 (15.8)	
ASA grade	I	3363 (49.9)	2390 (35.5)	986 (14.6)	< 0.001
	II	2366 (41.6)	2451 (43.1)	868 (15.3)	
	III	800 (37.9)	1026 (48.6)	287 (13.6)	
	IV	102 (34.5)	143 (48.3)	51 (17.2)	
	V	37 (44.0)	37 (44.0)	10 (11.9)	
Smoker	Never smoked	4786 (48.6)	3757 (38.1)	1310 (13.3)	< 0.001
	Current smoker	1063 (46.7)	883 (38.8)	330 (14.5)	
	Ex-smoker	655 (40.9)	741 (46.3)	206 (12.9)	
Pathology	Malignancy	742 (34.6)	1191 (55.6)	210 (9.8)	< 0.001
	Other abdominal	1536 (41.0)	1727 (46.1)	487 (13.0)	
	Infection	111 (38.0)	147 (50.3)	34 (11.6)	
	Appendicitis	2083 (47.9)	1483 (34.1)	785 (18.0)	
	Gallstone disease	2344 (51.1)	1504 (32.8)	742 (16.2)	
Urgency	Congenital	88 (38.9)	118 (52.2)	20 (8.8)	< 0.001
	Elective	3382 (46.9)	2962 (41.1)	871 (12.1)	
	Semielective	286 (38.3)	375 (50.3)	85 (11.4)	
Contamination	Emergency	3239 (43.8)	2834 (38.3)	1322 (17.9)	< 0.001
	Clean-contaminated	5713 (47.2)	4563 (37.7)	1818 (15.0)	
	Contaminated	681 (36.9)	915 (49.5)	251 (13.6)	
WHO checklist	Dirty	479 (38.6)	596 (48.0)	167 (13.4)	< 0.001
	No	2633 (60.6)	1310 (30.1)	404 (9.3)	
	Yes	4198 (38.9)	4771 (44.2)	1829 (16.9)	

P values are derived from χ^2 testing for categorical data.

ASA indicates American Society of Anaesthesiology; WHO, World Health Organisation.

RESULTS

Part 1. Cohort Study

Methods of Postdischarge Follow-up

Overall, 15358 of 16015 patients (95.9%) were discharged before 30 days postoperatively and were included in this analysis. Of these patients, 6907 underwent telemedicine review (45.0%), 6171 in-person review (40.2%), and 2280 inpatient only assessment (14.8%).

Use of Telemedicine

Telemedicine was used across 51 of 66 contributing countries spanning high ($n = 23$), middle ($n = 16$) and low-HDI ($n = 12$) settings (Fig. 1). In high-HDI settings 36.7% (3113/8492) of included patients were followed-up using telemedicine. The telemedicine follow-up rates were higher in both middle-HDI (61.4%, 3075/5006), and low-HDI settings (38.7%, 719/1860). Telemedicine was used for patients of both sexes (41.8%, of male patients, and 47.1% of female patients) and all age ranges, including both the youngest (2–20 year; 46.6%, 1003/2151) and oldest age groups (80–100 year; 31.8%, 154/485). Telemedicine was used to follow-up patients with a range of American Society of Anaesthesiology grades, underlying pathologies and presenting for both elective and emergency care (Table 1).

Characteristics of Patients by Follow-up Group

There were significant differences in the baseline risk characteristics of the groups that underwent telemedicine, in-person, and inpatient only follow-up. Notably, patients that underwent surgery for malignancy were less likely to have telephone review than in-person clinical review (34.6% vs 55.6%, $P < 0.001$). Patients undergoing emergency surgery were more likely to have telephone review than clinical review (43.8% vs 38.3%, $P < 0.001$). Patients from high income countries ($P < 0.001$), with gallstone disease or appendicitis as their indication for surgery ($P < 0.001$), or that underwent emergency surgery ($P < 0.001$) were most likely to have inpatient only assessment.

Reporting of SSI

In this study, 11.2% (1721/15358) of patients had an SSI reported, and 5.5% (843/15358) had an unknown SSI status. The rate of SSI reported was slightly lower with telemedicine (11.1%, 766/6907) and lower with inpatient only follow-up (5.7%, 129/2280) than with in-person follow-up (13.4%, 826/6171, $P < 0.001$). Of patients that had SSI reported, 44.5% (766/1721) of diagnoses were made using telemedicine, 48.0% (826/1721) in-person, and 7.5% (129/1721) with inpatient only assessment.

Figure 1 shows the unadjusted SSI rates by method of follow-up, stratified by HDI tertile. “Unknown” SSI status was higher in groups undergoing inpatient only assessment than telephone review or in-person clinical review groups; this difference was largest across middle-HDI and low-HDI settings ($P < 0.001$). Small differences were observed in reported SSI rates (unadjusted) following

TABLE 2. Observed Rates of Surgical Site Infection by Follow-up Strategy and Contamination Strata

Follow-up Method	Clean-contaminated, n/N (%)	Contaminated, n/N (%)	Dirty, n/N (%)
Overall	1151/12411 (9.3)	455/1984 (22.9)	367/1382 (26.6)
All included countries			
Telemedicine	514/5713 (9.0)	146/680 (21.5)	104/479 (21.7)
In-person	424/4440 (9.5)	225/905 (24.9)	160/581 (27.5)
Inpatient only	84/1814 (4.6)	22/246 (8.9)	19/166 (11.4)
Low and middle HDI countries only			
Telemedicine	171/1563 (10.9)	126/428 (29.4)	94/265 (35.4)
In-person	365/3014 (12.1)	104/419 (24.8)	74/162 (45.7)
Inpatient only	28/239 (11.7)	16/58 (27.6)	15/41 (36.5)

telemedicine and in-person review across high-HDI [7.3% (222/3043) vs 11.4% (432/3793)], middle-HDI [13.3% (396/2971) vs 12.9% (169/1305)] and low-HDI [20.7% (148/716) vs 22.8% (225/989)] countries. Unadjusted SSI rates with telephone follow-up and in-person clinical follow-up were comparable across strata of intra-abdominal contamination (Table 2, Supplementary Fig. 1, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>). Inpatient only assessment had a lower recorded rate of SSI in high-income settings [5.1% (69/1355)], but a higher rate of SSI reported in

middle-income [15.3% (42/274)], and low-income settings [26.1% (18/69)], respectively.

Our proposed casual model is displayed in Figure 2. Upon univariable analysis, the odds of reporting an SSI following telemedicine assessment (OR: 0.81, 0.73–0.90, $P < 0.001$) was lower than in-person (reference). After multivariable adjustment telemedicine assessment was associated with lower odds of reporting SSI than in-person review (OR: 0.73, 0.64–0.84, $P < 0.001$, Fig. 3). This was consistent in sensitivity analyses including patients that were alive at 30 days after surgery only (Supplementary Table 2, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>) that had a postoperative length of stay of 14 days or less (Supplementary Table 3, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>), elective cancer surgery only (Supplementary Table 4, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>) propensity score matched analysis (Supplementary Tables 5 and 6, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>), and on subgroup analysis by HDI group (Supplementary Fig. 2, Supplementary Digital Content 1, <http://links.lww.com/SLA/D998>). Whilst there was a higher 30-day POMR in patients that underwent in-person review than telemedicine review in unadjusted data (1.3%, 81/6056 versus 1.0%, 70/6721), there was no significant association between follow-up method and POMR in the adjusted model (Supplementary figure 3).

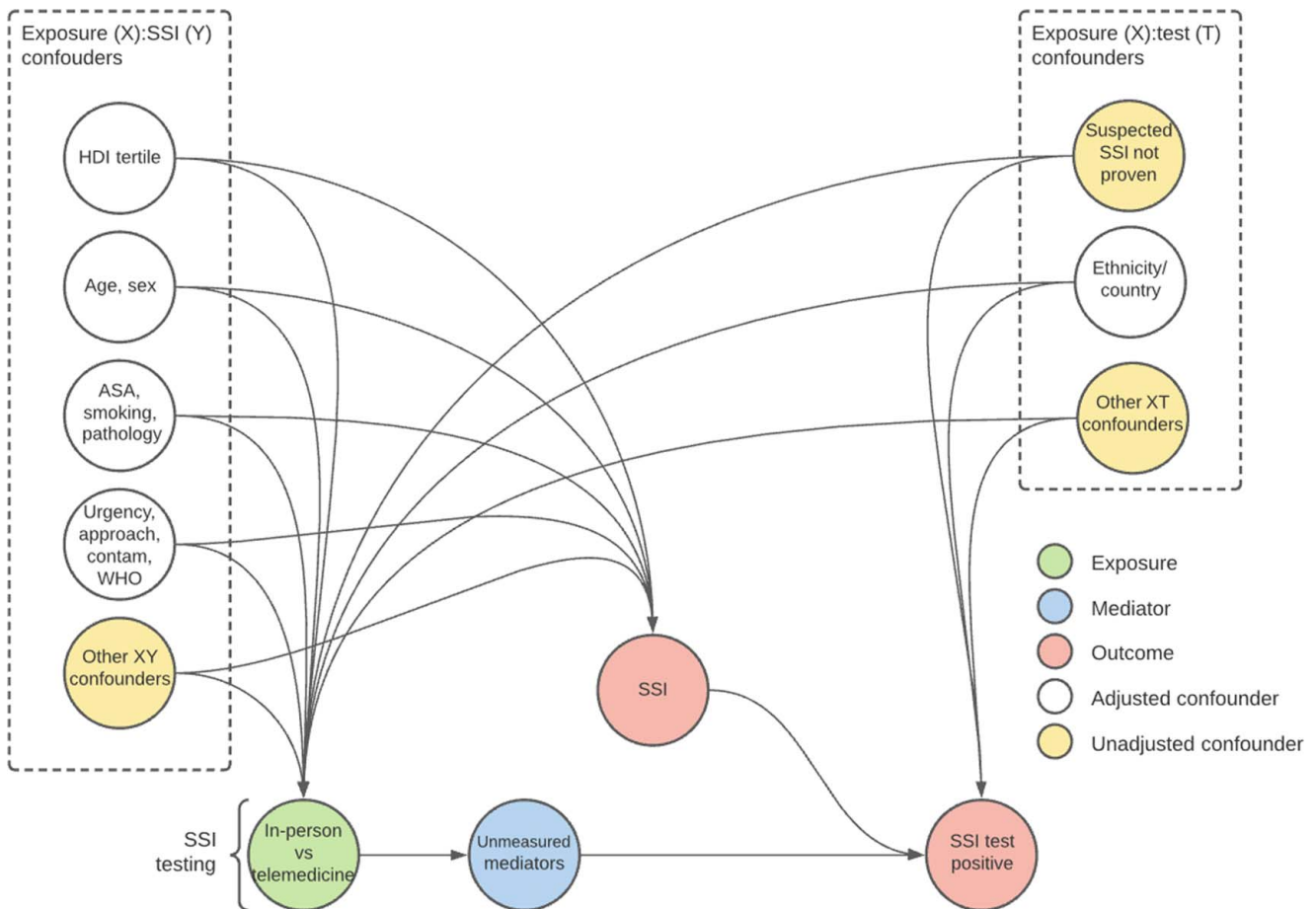


FIGURE 2. Directed acyclic graph displaying casual model between method of follow-up and SSI test positive (observed SSI).

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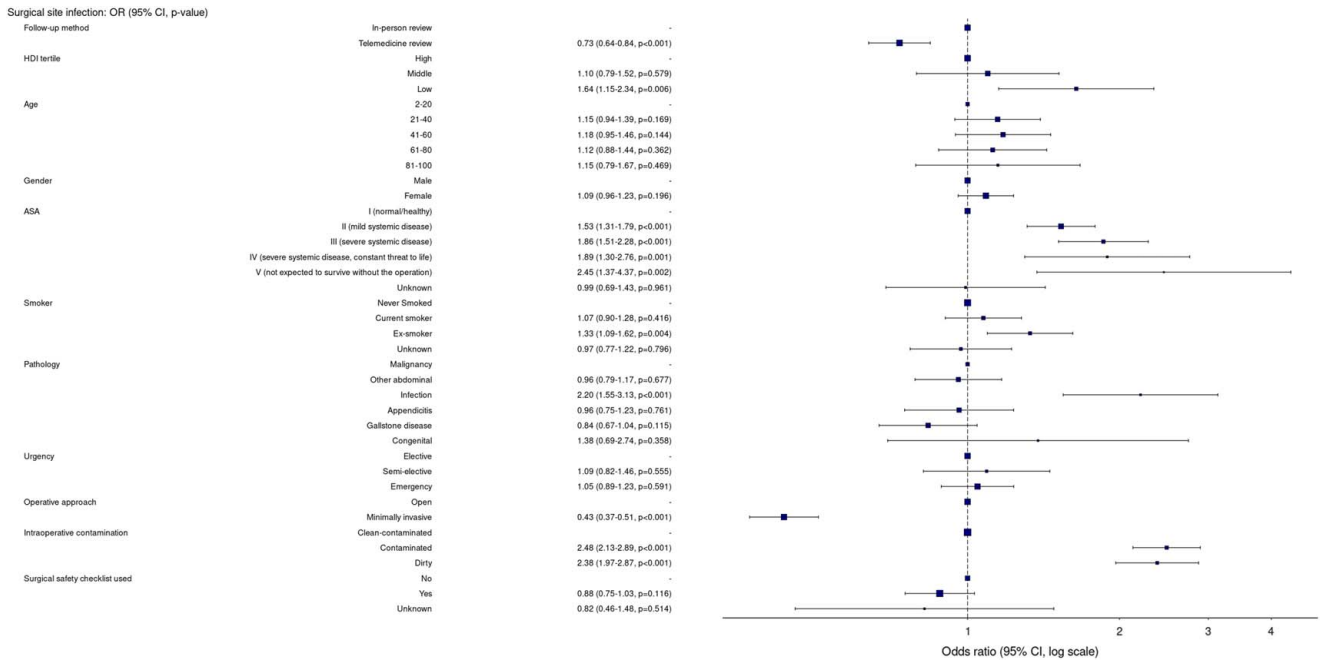


FIGURE 3. Forest plot of factors associated with reporting of postdischarge surgical site infection after abdominal surgery. A lower odds ratio conveys a lower adjusted odds of reporting a surgical site infection (ie, assumed to be under-detection of the true SSI rate). ASA indicates American Society of Anaesthesiology; WHO, World Health Organisation (Full model presented in Supplementary Table 1 Supplemental Digital Content 1, <http://links.lww.com/SLA/D998>).

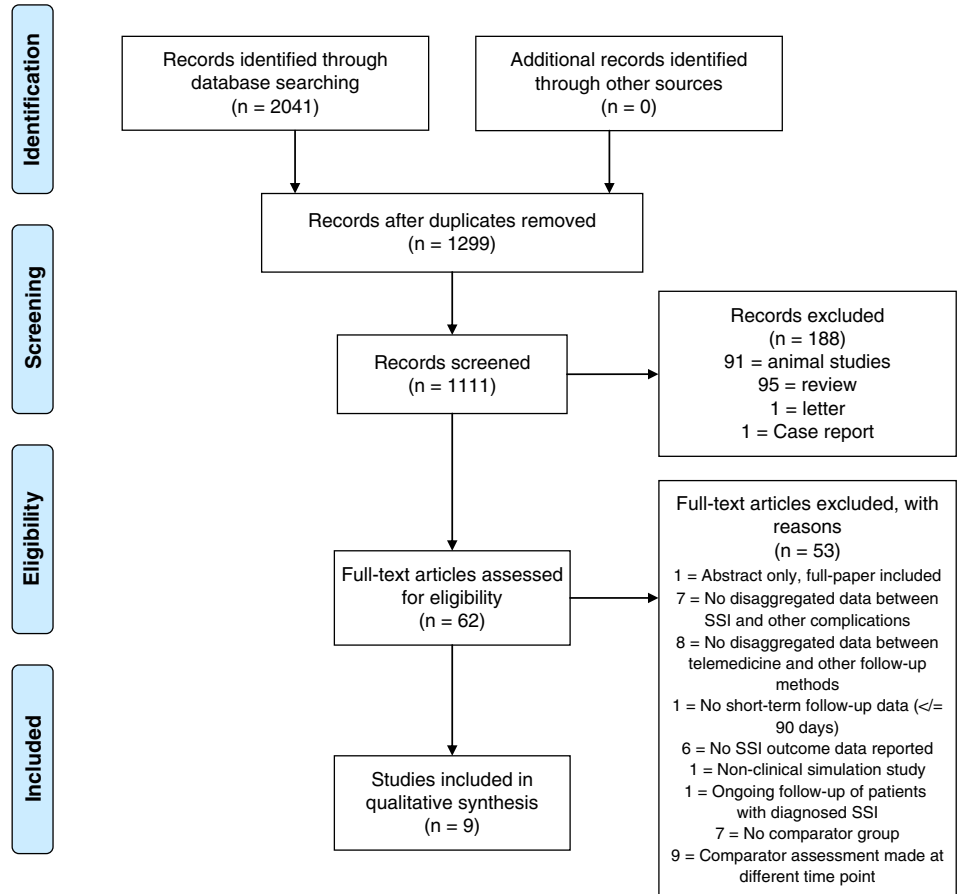


FIGURE 4. PRISMA flowchart of studies included in meta-analysis.

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TABLE 3. Rates of SSI Detected by In-person and Telemedicine Follow-up in Published Studies

References	Operation Types	HDI	SSI (Telemedicine)	Patients (Telemedicine)	Telephone Assessment	SSI (Comparator)	Patients (Comparator)	Comparator Assessment	Within patient Measurement
Comparison to in-person follow-up									
Abu-Sheasha et al ²⁵	All	Middle-income	34	254	PHE	32	309	Non-CDC	Paired
Pathak et al ²⁶	General surgery	Middle-income	10	380	Not stated	24	156	CDC	Unpaired
McIntyre et al ²⁷	Trauma	High-income	9	112	CDC	4	29	CDC	Unpaired
Reilly et al ²⁸	Orthopedics	High-income	8	105	CDC	6	105	CDC	Paired
Comparisons to other follow-up methods									
Bediako-Rowan et al ²⁹	General surgery	Middle-income	35	3007	PHE	161	1438	EHR	Unclear
Burlingame et al ³⁰	Obstetrics	High-income	45	868	Not stated	24	868	EHR	Unclear
Golub et al ³¹	General surgery	Middle-income	17	100	Not stated	15	100	EHR	Unclear
Pham et al ³²	Noncardiac	High-income	122	2853	Not stated	67	2853	EHR	Paired
Petrosillo et al ³³	General surgery, Gynecology	High-income	62	4041	CDC	31	184	Postal questionnaire	Unpaired
GlobalSurg cohort study data									
GlobalSurg Collaborative ¹⁵	General surgery	All	766	5964	Not stated	826	5261	In-person (CDC)	Unpaired
High income		High-income	222	2821	Not stated	432	3361	In-person (CDC)	Unpaired
Middle income		Middle-income	396	2575	Not stated	169	1136	In-person (CDC)	Unpaired
Low income		Low-income	148	568	Not stated	225	764	In-person (CDC)	Unpaired

PHE indicates Public Health England; EHR, Electronic Health Record.

Systematic Review and Combined Meta-analysis

Search Results

From 1299 deduplicated search results, 25 full papers reported an SSI rate detected using telemedicine. 28.0% had no comparator group (7/25), and 36.0% (9/25) compared telemedicine to assessment at a different time point (eg, in-hospital vs 30-day telemedicine assessment). Nine eligible studies were therefore included.^{25–33} Summary data from the cohort study in *Part 1* was combined with these 9 studies for qualitative synthesis (Fig. 4).

Study Characteristics

Of the included studies, 66.7% (6/9) were published within the last 5 years (2015–2020).^{25,26,29–32} Eight were prospective cohort studies, with 1 retrospective study.³⁰ Most reported data from high-income countries (55.6%, 5/9)^{27,28,30,32,33}; 1 was from an upper-middle income country³¹ and 3 from lower-middle income countries.^{25,26,29} No data from low-income countries or multi-country studies were reported. Of included articles, 44.4% (4/9) reported outcome assessment in patients undergoing general surgery,^{26,29,31,33} 22.2% (2/9) in trauma and orthopedics,^{27,28} 11.1% (1/9) in obstetric surgery,³⁰ and 22.2% (2/9) in all non-cardiac surgery.^{25,32} There was a moderate or severe risk of bias in all included studies (Supplementary Fig. 4, Supplemental Digital Content 1, <http://links.lww.com/SLA/D998>).

Use of Telemedicine

The proportion of patients with follow-up using telemedicine ranged from 45% to 96%. Study sizes ranged from 141 to 11225 patients. The pooled proportion of patients with telemedicine follow up on meta-analysis was 64% (95% CI: 55%–73%). There was very high heterogeneity ($I^2 = 100%$, $P < 0.001$).

Delivery of Telemedicine

Four included studies did not state a standardized schedule for outcome assessment. 22.2% (2/9) used the Public Health England Postdischarge Surveillance Questionnaire^{25,29} and 33.3% (3/9) used questions based on CDC criteria.^{27,28,33} 77.8% (7/9) were used as a one-off assessment at 30 postoperative days,^{25–27,30–33} with 2 using serial postoperative assessments.^{28,29}

Comparison of Telemedicine to In-person Follow-up

Four studies involved a comparator of telemedicine to in-person follow-up method^{25–28} and were included in meta-analysis of SSI rates reported, combined with the cohort study data (5 studies in total). Two studies had paired within-subject measurements at the same time point,^{25,28} and 2 had measurements at the same time point but in different patient groups.^{26,27} Only 2 (50%) compared telemedicine to an in-person assessment according to US Centre for Disease Control criteria (Table 3). In the random effects meta-analysis, the rate of SSI reported using telemedicine was significantly lower in the telemedicine group than the in-person group (0.67, 95% CI: 0.47–0.94). There was some evidence of between-study heterogeneity, but this did not have a significant effect on the random effects meta-analysis ($I^2 = 0.45$, 0.00–0.78, $P = 0.12$; $\tau = 0.27$, 0.00–0.93; Fig. 5). There was no significant evidence of funnel plot asymmetry (Supplementary Fig. 5, Supplemental Digital Content 1, <http://links.lww.com/SLA/D998>, $P = 0.326$).

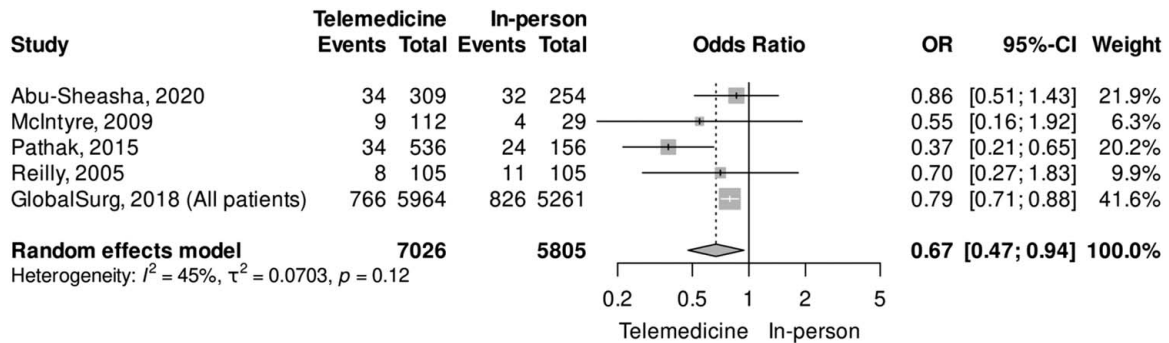


FIGURE 5. Forest plot of rates of SSI reported by telemedicine and in-person follow-up on meta-analysis. Odds ratios displayed describes a comparison of the odds of patients having an SSI reported with telemedicine versus in-person follow-up (ie, a reduced odds ratio conveys a lower rate of SSI reported with one method in comparison to the other, and vice versa).

Comparison of Telemedicine to Other Follow-up Methods

Five studies compared telemedicine to a follow-up method that did not require in-person review (eg, Electronic Health Records or postal questionnaire).^{29–33} These are summarized in Table 3 but excluded in the meta-analysis of SSI rates. Four of 5 studies had a higher rate of reporting of SSI in the telemedicine group than the electronic health records or postal questionnaire group. One study had a much lower SSI rate reported by telemedicine than electronic health records (1.1% vs 11.2%), but the 2 methods were applied in clearly different patient populations (responders to a postal questionnaire vs nonresponders).²⁹

DISCUSSION

This cohort study and meta-analysis identified that use of telemedicine for wound assessment postdischarge is feasible across settings. The adjusted rate of SSI reported using telemedicine in patients that underwent postdischarge assessment was lower than with in-person follow-up in the international cohort study, raising concerns of underreporting of SSI. This was robust to several sensitivity analyses, a propensity score-matched model and across HDI settings. This analysis of real-world, global data suggests that telemedicine methods used in the pre-pandemic setting may risk patient safety or introduce bias to research studies. This was corroborated in the combined meta-analysis. The studies included were of low quality, and rarely used standardized tools. High-quality frameworks for remote assessment of SSI must be evaluated and adopted as telemedicine is upscaled globally.

Telemedicine for follow-up of surgical patients holds significant promise during the SARS-CoV-2 pandemic recovery effort. The high connectivity of global telecommunication networks opens opportunities for telemedicine in both well-resourced and resource constrained settings.³⁴ Efficient methods for surgical follow-up may be most relevant in LMICs where patients may already travel long distances or take time out of work to return to hospital after discharge, and health systems face severe resource limitations.^{35–39} During future SARS-CoV-2 outbreaks, use of telemedicine may reduce the risk of exposure in hospital outpatient settings.² During the postpandemic recovery, it may help alleviate the growing backlog of outpatient appointments and investigations that health systems face around the world.^{40–42} However, as the use of these methods increases, it is important that the quality of assessment does not decrease.

Delayed or missed identification of postoperative complications can lead to failure to rescue and death, more severe sequelae, and increased costs^{21,43}; these events, while rare, have the potential to undermine the benefits of telemedicine, particularly for higher-risk patients and operations.⁴⁴

Two different standardized tools for identification of SSI using telemedicine (Centre for Disease Control Criteria and Public Health England Postdischarge Questionnaire) were identified in the systematic review, but neither have been formally adapted or validated for use in telemedicine. A universal outcome reporter “Bluebelle” Wound Healing Questionnaire has demonstrated promise as tool for remote detection of SSI, demonstrating excellent discrimination and reliability^{45,46}; however, this has only undergone evaluation in a single language in one country, and cultural and linguistic adaptation and validation to support international application.⁴⁷ No included studies used videography to help identify SSI; this may prove a useful adjunct to future development in this area.

SSI has been identified as a key priority to improve the health of patients undergoing surgery worldwide, particularly in low resource settings.^{48,49} Lessons from use of telemedicine for wound assessment may be generalizable to other common complications of surgery, but bespoke tools may be required for each to ensure accurate identification of different events. Quality-assured digital methods for remote assessment will also have high value for use in pragmatic international trials, where delivery can be made more efficient, and more benefit for more patients can be realized at a lower time and resource cost.^{50,51}

This study has several limitations. First, we infer that the “gold standard” in-person assessment represents the true SSI rate. We are unable to assert from our data whether SSI is over-reported using in-person follow-up or under-reported using telemedicine where a difference is observed. Second, we assume that the differences in reported SSI rates are unrelated to differences in patient characteristics after risk-adjustment. While we used multilevel models to adjust for several confounders, there is a risk of residual selection bias. Third, the quality of studies included in meta-analysis was low. We excluded studies that reported SSI when telemedicine was used for a clearly different patient populations (eg, different subgroups of patients, responders vs nonresponders, different geographical areas), with no comparator group, or a comparator group at a different time point (eg, in-hospital vs 30-day remote assessment). However, remaining studies demonstrated some “selection” of patients for telemedicine follow-up, no studies were randomized, and all

were at moderate or severe risk of bias. Fourth, we do not have paired within-patient measures of SSI in-hospital and post-discharge at 30 days, and we are therefore unable to fully account for changes in patient selection to a particular follow-up modality as a result of inpatient infection. This may have exaggerated the difference between telephone and in-person follow-up; however, our analysis of postoperative mortality did not indicate a serious risk of reverse causation. Fifth, as the patients with “inpatient only” follow-up had no postdischarge wound assessment they were effectively “lost to follow-up” for the purposes of the primary 30-day analysis. As we do not know the intended follow-up method (ie, whether telemedicine or in-person follow-up was planned, but only inpatient data were collected) we are unable to fully explore the impact of attrition bias on the primary comparison. Sixth, there is a further risk of reverse causation in linking patients with inpatient only assessment and a lower observed SSI rate (ie, those without features of SSI postoperatively may be less likely to reinteract with clinical services). As such, this group were excluded from multivariable analyses, and we recommend caution in interpretation. Seventh, we were unable to differentiate here between different methods of remote wound assessment (ie, telephone vs video), although from ongoing work across our network it is likely that a majority of assessment would have been telephone-based.⁴⁷ Eighth, the cohort study used a pragmatic observation methodology and did not standardize training or delivery of telemedicine. This should therefore be interpreted as the real-world effectiveness of telemedicine, rather than the potential efficacy of telemedicine in an optimized system.⁵² Finally, we have only included one, common postoperative complication in our synthesis. These data set the scene for a broad research agenda to identify and validate tools for remote digital assessment across diverse patient groups and operation types. The rapid upscaling of telemedicine during the SARS-CoV-2 pandemic highlights this as an urgent research priority for the global surgical community.

ACKNOWLEDGMENTS

The authors thank the organizations assisting in dissemination and/or translation (alphabetical): Asian Medical Students' Association (AMSA), Association of Surgeons in Training (ASiT), College of Surgeons of East, Central & Southern Africa (COSECSA), Cutting Edge Manipal, Egyptian Medical Student Research Association (EMRA), International Collaboration For Essential Surgery (ICES), International Federation of Medical Student Associations (IFMSA), Italian Society of Colorectal Surgery (SICCR), Lifebox Foundation, School of Surgery, Student Audit and Research in Surgery (STARsurg), The Electives Network, United Kingdom National Research Collaborative, World Society of Emergency Surgery (WSES), World Surgical Association (WSA).

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