Post-Caesarean Section Surgical Site Infection Surveillance Using an Online Database and Mobile Phone Technology

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Abstract

Background: Obstetric surgical site infections (SSIs) are common and expensive to the health care system but remain under reported given shorter postoperative hospital stays and suboptimal post-discharge surveillance systems. SSIs, for the purpose of this paper, are defined according to the Center for Disease Control and Prevention (1999) as infection incurring within 30 days of the operative procedure (in this case, Caesarean section [CS]).

Primary Objective: Demonstrate the feasibility of real-life use of a patient driven SSIs post-discharge surveillance system consisting of an online database and mobile phone technology (surgical mobile app – how2trak) among women undergoing CS in a Canadian urban centre.

Secondary Objective: Estimate the rate of SSIs and associated predisposing factors.

Methods: Prospective cohort of consecutive women delivering by CS at one urban Canadian hospital. Using surgical mobile app—how2trak—predetermined demographics, comorbidities, procedure characteristics, and self-reported symptoms and signs of infection were collected and linked to patients' incision self-portraits (photos) on postpartum days 3, 7, 10, and 30.

Results: A total of 105 patients were enrolled over a 5-month period. Mean age was 31 years, 13% were diabetic, and most were at low risk of surgical complications. Forty-six percent of surgeries were emergency CSs, and 104/105 received antibiotic prophylaxis. Forty-five percent of patients (47/105) submitted at least one photo, and among those, one surgical site infection was detected by photo appearance and self-reported symptoms by postpartum day 10. The majority of patients whom uploaded photos did so multiple times and 43% of them submitted photos up to day 30. Patients with either a diagnosis of diabetes or self-reported Asian ethnicity were less likely to submit photos.

Conclusions: Post-discharge surveillance for CS-related SSIs using surgical mobile app how2trak is feasible and deserves further study in the post-discharge setting.

Key Words: Caesarean section, surgical wound infection, cell phone

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Résumé

Contexte : Les infections du site opératoire (ISO) sont courantes en obstétrique et représentent d'importants coûts pour le système de santé, mais elles demeurent sous-déclarées en raison de séjours à l'hôpital écourtés et de systèmes de surveillance après congé sous-optimaux. Aux fins du présent article, on entend par ISO toute infection survenue dans les 30 jours suivant une intervention approuvée par le National Healthcare Safety Network (ici, une césarienne), ce qui correspond à la définition des Centres pour le contrôle et la prévention des maladies (1999).

Objectif primaire : Démontrer la faisabilité d'utiliser un système de surveillance des ISO après congé reposant sur la participation des patientes et comprenant une base de données en ligne et une application pour téléphone cellulaire (how2trak) auprès de femmes ayant subi une césarienne dans un centre urbain du Canada.

Objectif secondaire : Estimer la prévalence des ISO et des facteurs prédisposants connexes.

Méthodologie : Il s'agissait d'une étude de cohorte prospective portant sur les femmes consécutives ayant accouché par césarienne dans un hôpital canadien en milieu urbain. Une application mobile, how2trak, a été utilisée pour recueillir des données prédéterminées – paramètres démographiques, comorbidités, caractéristiques de l'intervention et signes et symptômes autodéclarés d'infection – puis pour lier ces données à des photos prises par les patientes de leur incision aux jours 3, 7, 10 et 30 après l'accouchement.

Résultats : Au total, 105 patientes ont participé à l'étude sur 5 mois. L'âge moyen était de 31 ans, 13 % des participantes étaient diabétiques, et la plupart présentaient un faible risque de complications chirurgicales. En tout, 46 % des interventions étaient des césariennes d'urgence; 104 patientes sur 105 ont reçu une antibioprophylaxie. Quarante-cinq pour cent des patientes (47/105) ont envoyé au moins une photo; une infection du site opératoire a été détectée d'après la photo et les symptômes déclarés par la patiente au jour 10. La majorité des patientes qui ont téléversé des photos l'ont fait plus d'une fois, et 43 % ont soumis des photos jusqu'au jour 30. Les patientes diabétiques et celles qui se disaient d'origine asiatique étaient moins susceptibles d'envoyer des photos.

Conclusions : La surveillance après congé des ISO liées à une césarienne au moyen de l'application mobile how2trak est faisable, et le recours à cette approche devrait être approfondi.

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INTRODUCTION

Surgical site infections are a significant contributor to patient morbidity[1] and increased health care spending, at an estimated annual cost of seven billion US dollars on hospital readmissions and post-discharge care for surgical wounds.[2] CSs have unique infectious risks related to potential pathogenic microorganisms from the skin or vagina resulting in uterine incision cellulitis, pelvic cellulitis, and pelvic abscesses.[3] CS-related surgical site infections are usually polymicrobial: gram-negative bacilli, enterococci, group B streptococci, and anaerobes. A substantial proportion of CSs are done on an emergency basis, and emergency surgeries predict a higher rate of postoperative complications.[4] In the era of universally recommended antibiotic prophylaxis prior to CS SSIs seem to affect 3% to 5% of women,[5–7] but prior studies had placed the rate of infection upwards of 15%.[8] Several interventions, used mostly in conjunction, have been consistently found to decrease CS-related SSI rates, and include: antibiotic prophylaxis 1 hour prior to skin incision,[9] chlorhexidine for antiseptic skin preparation, diabetic serum glucose control, normal body core temperature, wound irrigation post–uterine closure, subcutaneous suture >2 cm depth and transverse incision.[10]

ABBREVIATIONS

ASA	American Society of Anesthesiologists
NNIS	Center for Disease Control National Nosocomial Infections Surveillance
PDS	post-discharge surveillance
PROM	premature rupture of the membranes
SSI	surgical site infection

Early discharge from hospital (<48 hours) after CS is common, and reduces the opportunity for surveillance and determining "real" prevalence of the SSI rate. The Centre for Disease Control and Prevention estimates that up to 84% of SSIs are diagnosed postoperatively after hospital discharge.[11] Post-discharge surveillance following CS has been shown to increase detection of SSIs by up to 71%.[12,13] PDS involves following a patient for 3–30 days after hospital discharge to ascertain whether a patient has developed an SSI. The Canadian Patient Safety Institute Safer Healthcare Now[14] recommends tracking infections in surgical patients for up to 30 days postoperatively. Surgeries with appliance insertion (e.g., hip/knee replacement) require up to one year surveillance for surgical site infection.

how2trak is an innovative surveillance system that uses online database and mobile phone technology to support patients and health care providers for post-hospital discharge community-based surveillance and management and chronic conditions. It was initially developed for community-based comprehensive wound care but has since been adapted to provide a surgical site infection mobile application, compatible with all smartphones. The patient questions developed for the application were based on an exhaustive review of relevant research literature as well as a panel of clinical experts to ensure content validity. It offers a user-friendly interface for both health care workers and patients and supports mobile device input with minimal operator training requirements at low data management costs.

Given the challenges in tracking SSIs once a patient has been discharged home, this innovation has the potential to provide an early warning of potential SSIs, as well as consistent, on-going data to monitor patient progress.

This proof of concept study is presented as a new quality improvement opportunity for CS SSI PDS.

Primary Objective

As a proof of concept, the purpose of this study was to demonstrate the feasibility of real-life use of a patient-driven SSI PDS system consisting of an online database and mobile phone technology (surgical mobile app – how2trak) among women undergoing CS in a Canadian urban centre.

Secondary Objective

Estimate the rate of SSIs occurring among patients delivering by CS in one urban mid-Western hospital, routine presurgical antibiotic prophylaxis, and associated predisposing factors.

METHODS

Consecutive women delivering by CS at one urban Canadian centre (5000 deliveries per year, 28% CS rate) were approached to participate in the study within 24 hours of delivery. Even though every CS delivery was eligible to participate, convenience sampling dictated by availability of research assistant (3 days/week, 9 AM to 4 PM) was used. Other eligibility criteria involved having a cellphone in the household, being able to speak English, and to understand and give consent to participate.

The existing how2trak surgical site infection module was adapted for CS following input from nursing, infectious diseases, and obstetrics in the spring of 2014. Standard SSI risk assessment tools such as American Society of Anesthesiologists Physical Status Classification System and Center for Disease Control National Nosocomial Infections Surveillance (Appendix) already imbedded on how2trak SSI module were kept even though they may not adequately stratify risk for obstetric patients. For the purposes of this study, the ASA Physical Status Classification System was used prior to its October 2014 revision,[15] where the ASA recommended "healthy" pregnant patients classified as ASA II (i.e., patient with mild systemic disease without substantive functional limitations).

The following information was collected once consent to participate had been obtained using how2trak application on a portable device: demographics, maternal diabetes, and presence of premature rupture of the membranes, and ASA and NNIS scores (see Appendix for definitions of ASA and NNIS scores). Interventions for prevention of surgical site infections, as detailed on Safer Health Care Now Guidelines[14] (antibiotic prophylaxis, antiseptic prophylaxis, postoperative prophylactic, or therapeutic antibiotic therapy [24 hours post-surgery], abdominal/pubic hair removal by clippers, perioperative glucose control and normothermia) were collected from chart as well. The American College of Surgeons wound classification schema[16] was used as follows: Class I: clean (scheduled CS, no labour), Class II: clean contaminated (labour), Class III: contaminated (labour with PROM), or Class IV: dirty infected (maternal diagnosis of chorioamnionitis).

Participants were instructed to download the surgical mobile app, how2trak, and upload a photo of their incision once a day on postpartum days 3, 7, 10, and 30. At the time of photo upload, they were asked for signs and symptoms of infection: induration (redness and swelling), pain, warmth and fever, and whether or not they sought medical attention. If so, the app prompted them to provide name and contact of health care provider or agency where they were seen.

In preparation for the study, community care liaison was established. Outpatient physician's offices (for all obstetricians working at study hospital) and homecare nursing were briefed about the study and were asked to record patient encounters regarding an SSI after hospital discharge on a standardized form that included information on antibiotic administration (duration and dosing), wound characteristics (exudate, surrounding skin appearance) and signs and symptoms of an SSI (as per CDC scale).[17]

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Statistical Analysis

Significant usage patterns were examined across several categorical variables (age range, ethnicity, diabetes diagnosis, emergency versus scheduled CS, surgical category, ASA and NNIS scores). The significance of association between each categorical variable and photo submission via mobile application usage was assessed using Chi-squared test (χ^2). A P-value of <0.05 was considered as the level of significance.

Ethical approval was obtained from the Conjoint Health Research Ethics Board at the University of Calgary: REB 13-0592 for December 3, 2013 until December 3, 2014.

RESULTS

One hundred and five (N = 105) participants were enrolled over a 4-month period. Mean age was 30 years (range 20−44 years), 46% were Caucasian and 37% were Asian, 13% were diabetics, and most were at low-risk of surgical complications: 60% were ASA score 1 and 94% had a NNIS score of 0.

Forty-six percent of surgeries were emergency CS and 95% received a regional anesthetic. Sixty-percent of CSs were classified as clean (scheduled CS, no labour), 27% were clean contaminated (participants laboured prior to CS), 24% were contaminated (participants laboured prior to CS and had PROM, median time 7 hours) and 1% was dirty infected (maternal diagnosis of chorioamnionitis).

Almost all participants (102/105) received antibiotic prophylaxis for SSI prevention: 75% between 30 and

60 minutes before skin incision and 23% 0–30 minutes before skin incision; only two participants received antibiotic prophylaxis after skin incision, and another did not receive antibiotic prophylaxis at all. Antiseptic prophylaxis was documented for all participants; 57% with chlorhexidine and 43% with iodine. Postoperative prophylactic or therapeutic antibiotic therapy (>24 hours after surgery) was prescribed for 48/105 participants. In the perioperative period, glucose control—defined as evidence of blood glucose assessment (and/or treatment as indicated)—was documented for 89/105 (85%) participants and 101/105 (96%) had normal temperature. Only one participant had abdominal/pubic hair removed by clippers. Metal skin staples were used for skin closure for all but two participants.

Post-discharge at home, 45% of patients (47/105) submitted at least one photo, and among those, one SSI was detected by photo appearance and self-reported symptoms by postpartum day 10, for an SSI rate of 2.3% among those that submitted a photo and 0.9% among all participants. The participant that reported SSI had had an emergency CS while undergoing induction of labour for polyhydramnios; she received antibiotic prophylaxis within 30 minutes of skin incision and antiseptic prophylaxis with chlorhexidine. Participant reported warmth, induration to touch, and pain at 6/10 using app how2trak; this was evident to the surgeon reviewing the photograph sent by the patient. Communication with her family physician indicated she received a 7-day prescription of cephalexin.

Eighty-five percent of the participants who uploaded photos (40/47) did so multiple times. Forty-three percent of participants (20/47) uploaded a day 30 photo. The participants who only uploaded one photo (n = 7) did so by postpartum day 10. Participants who uploaded photos were compared against those who did not (Table). Sixty-one percent of Caucasians uploaded at least one photograph versus 30% of other combined self-declared ethnicities ($P = 0.041$, using chi-squared contingency table method). Forty-nine percent of those without a diagnosis of diabetes uploaded at least one photograph compared with only 14% of those with diabetes ($P = 0.030$, using chi-squared contingency table method). Age, emergency versus scheduled CS, surgical category, and ASA and NNIS scores were not associated with any significant relationship to uploading the photographs.

DISCUSSION

In the present health care environment, surgical quality improvement requires accurate tracking and benchmarking of postoperative adverse events. Challenges inherent to PDS include: high degree of heterogeneity and lack of standardization in methods and statistical tools to do so; access to patients once they have left the hospital; difficulties coordinating multiple health care providers in both private and public sectors; delay collecting information; and importantly, costs associated with PDS. Mobile communication technology has the potential to overcome some of the challenges posed by PDS as it facilitates real-time data collection and access to otherwise hard to reach populations and settings. For example, PDS of SSI, using mobile phones in a rural setting in India resulted in a follow-up rate of 74.5% with an SSI rate of 6.3%.[18]

In this context, an innovative surveillance system like how2trak that uses an online database and mobile phone technology for patients and care providers to actively participate in community-based SSI surveillance with minimal training requirements and low data management costs is an attractive alternative to other PDS systems for CS-related SSIs.

This “proof of concept” pilot study in an ethnically diverse population demonstrated that at least 45% of participants actively and successfully participated in the CS post-discharge SSI surveillance process using how2trak despite stressors inherent to the postpartum period. An interesting outcome of the study was that, even in the absence of reminders or follow-up calls, a substantial proportion of participants (43%) remained active in the surveillance using how2trak to submit a photo up to postoperative day 30.

This cohort was representative of the average obstetric case-mix at Canadian urban hospitals: mean age was 31 years, 13% were diabetic, most were at low risk of surgical complications, CS rate was 28%, and 46% of CSs were done on an emergency basis. Adherence to Safer Health Care Now Guidelines for the prevention of SSI was very high in this cohort: 95% to 100% received timely antibiotic prophylaxis, active management of hyperglycemia, avoidance of hair removal with razors, and antiseptic prophylaxis.

Using how2trak, this study reports a CS-related SSI rate of 0.9% among all participants and 2.3% among those who submitted a photo, which is comparable with reported CS-related rates in institutions where quality improvement initiatives incorporating Safer Health Care Now Guidelines have been instituted (i.e., 4.9% from 16%[19] and 3.24% from 14%).[10] Older PDS studies reported CS-related SSI in the 6% to 13% range,[20,21] using community midwives or a combination of telephone calls, health care provider

Table. Participant characteristics by photo submission

	Number of patients $N_{Total} = 105$ *N (of N_{Total})* (%)	Number of photo submitters $N_{Total} = 47$ *N (of N_{Total})* (%)	Number of non- photo submitters $N_{Total} = 58$ *N (of N_{Total})* (%)
Maternal age, years ($\mu = 30.2$, $\sigma = 6.39$)			
17.4 − 23.8 (μ-2σ) − (μ-σ)	7 (6.7)	1 (2.1)	6 (10.3)
23.8 − 30.2 (μ-σ) − (μ)	44 (41.9)	23 (48.9)	21 (36.2)
30.2 − 36.6 (μ) − (μ+σ)	40 (38.1)	17 (36.2)	23 (40.0)
36.6 − 43.0 (μ+σ) − (μ+2σ)	11 (10.5)	4 (8.5)	7 (12.1)
Diabetes			
Yes	14 (13.3)	2 (4.3)	12 (20.7)
Ethnicity			
African	10 (9.5)	4 (8.5)	6 (10.3)
Asian	39 (37.1)	10 (21.3)	29 (50.0)
Caucasian	49 (46.7)	30 (63.8)	19 (32.8)
Hispanic	1 (0.9)	1 (2.1)	0 (0.0)
Non-disclosed	6 (5.7)	2 (4.3)	4 (6.9)
Emergency or scheduled			
Emergency	48 (45.7)	21 (44.6)	27 (46.6)
Scheduled	57 (54.3)	26 (55.3)	31 (53.4)
Premature rupture of membranes			
Yes	30 (28.0)	14 (29.8)	16 (27.5)
NNIS score			
0	99 (94.2)	46 (97.8)	53 (91.3)
1	5 (4.7)	1 (2.1)	4 (6.9)
2	1 (0.9)	0 (0.0)	1 (1.7)
ASA score			
1	63 (60.0)	29 (61.7)	34 (58.6)
2	40 (38.1)	18 (38.3)	22 (37.9)
3	1 (0.9)	0 (0.0)	1 (1.7)
4	1 (0.9)	0 (0.0)	1 (1.7)
Surgical category			
Class I: clean	63 (60.0)	26 (55.3)	37 (63.8)
Class II: clean-contaminated	27 (25.7)	14 (29.8)	13 (22.4)
Class III: contaminated	14 (13.3)	7 (14.9)	7 (12.1)
Class IV: dirty-infected	1 (0.9)	0 (0.0)	1 (1.7)

questionnaires, and review of outpatient medical records − all of which are resource-intensive and costly PDS methods.

Even though ideal PDS methods have not been well defined in the literature, it does seem warranted to consider a method that is robust and of shorter duration of the PDS.[22] With the added strength of evidence-based SSI questions for patients and quality photos of the incision site for surgeon review, further exploration of the surgical mobile app—how2trak—is reasonable given that mobile phone technology is widely accessible nowadays and surveillance data is fed straight from the source to a secure database. The ability of the patient to enter information based on research related to infection surveillance provided the surgeon with current data. The ability of the patient to take photos of the incision at timed intervals up to post-operative day 30 allowed for surveillance without the new mother having to leave home for an office visit or attend the emergency department for follow-up when incision healing continued along a normal trajectory. The fact that subjects did not require any prompting to use the application would indicate a general comfort level with use of this technology. This approach of the how2trak SSI application promotes self-care, all at low operator training requirements and low maintenance costs.

Several limitations in a proof of concept study were identified and could be explored in larger, more comprehensive studies using this application. For example, the number of eligible women who declined participation (and their reasons) would provide information to perhaps increase uptake. It was identified that several potential participants did not feel comfortable with English; given the multilingual nature of Canadian society, it would be of benefit to offer the app in other languages. Information regarding the family demographic (e.g., support system, number of other children at home) and socioeconomic/educational information could also inform the successful deployment of the how2trak mobile app for this population.

Results indicating a diagnosis of diabetes and Asian background were factors in a low adherence to the study instructions must be regarded with some caution. The small convenience sample and lack of additional contextual data (such as cultural practices, knowledge of written English, comfort level with mobile technology products, locus of control) might have provided a more granular understanding of the features affecting these two items and would be recommended for inclusion in future studies. Additionally, patient experience (qualitative) research could help uncover the lack of participation on the part of a cohort of self-identified Asian women and women with diabetes to identify possible barriers to utilization of the mobile app.

The focus of this paper was the proof of concept study, to explore the feasibility of use of a mobile app for CS patients to provide usable data for SSI post-discharge from hospital. The actual features of the application and its utility from the perspective of the surgeon were not part of this particular study. Within the how2trak mobile app, the surgeon has the ability to review each patient's entries (photos and response to questions related to signs/symptoms of SSI) and provide direction through the app itself, regarding disposition of a patient requiring follow-up (a scheduled office visit or homecare nursing, etc.). Other studies, with a triangulated design methodology, could address the limitations identified above. Gathering reliable data regarding SSI post-discharge has significant challenges, as described earlier in this paper. It would be relevant to compare post-discharge SSIs in a sample of control/mobile SSI app users, where SSI-related emergency department visits/hospital admissions and doctor office visits are tracked. In addition, using this mobile application in a study with a larger sample (e.g., multi-site) would provide more data that could assist in developing predictive modeling for the later-onset SSI post-CS.

CONCLUSION

PDS for CS-related SSIs using an online database and mobile phone technology (surgical mobile app—how2trak) was feasible in a Canadian-urban setting, with 43% uptake up to 30 days post-CS. This outcome, based on a convenience sample of women post-CS, would indicate that this mobile app for SSI surveillance deserves further study regarding utility in identifying, managing, and tracking any type of SSI post-discharge, as well as hospital readmissions/visits to the emergency department and patient satisfaction.

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APPENDIX

American Society of Anesthesiologists (ASA) Physical Status Classification System[a]

ASA PS Classification	Definition	Examples, including, but not limited to:
ASA I	A normal healthy patient	Healthy, non-smoking, no or minimal alcohol use
ASA II	A patient with mild systemic disease	Mild diseases only without substantive functional limitations. Examples include (but not limited to): current smoker, social alcohol drinker, pregnancy, obesity (30 $<$ BMI $<$ 40), well-controlled DM/HTN etc
ASA III	A patient with severe systemic disease	Substantive functional limitations; One or more moderate to severe diseases. Examples include (but not limited to): poorly controlled DM or HTN, COPD, morbid obesity (BMI $\geq$40), active hepatitis, alcohol abuse etc
ASA IV	A patient with severe systemic disease that is a constant threat to life	Examples include (but not limited to): recent ($<$3 months) MI, CVA, TIA, or CAD/stents, ongoing cardiac ischemia or severe valve dysfunction, etc.
ASA V	A moribund patient who is not expected to survive without the operation	Examples include (but not limited to): ruptured abdominal/thoracic aneurysm, massive trauma, intracranial bleed with mass effect, etc.
ASA VI	A declared brain-dead patient whose organs are being removed for donor purposes	

PS: physical status; DM: diabetes mellitus; HTN: hypertension; COPD: chronic obstructive pulmonary disease; MI: myocardial infarction; CVA: cerebrovascular accident; TIA: transient ischaemic attack; CAD: coronary artery disease.

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[a]Examples were added on October 15, 2014, by the ASA House of Delegates.

CENTER FOR DISEASE CONTROL NATIONAL NOSOCOMIAL INFECTIONS SURVEILLANCE (NNIS) BASIC RISK INDEX

The NNIS risk basic risk index is procedure-specific and applied to prospectively collected surveillance data. The index values range from 0 to 3 points. One point is scored for each of the following when present:

(1) a patient with an ASA Physical Status System $>$II

(2) an operation classified as contaminated or dirty-infected, and (3) an operation lasting over T hours, where T depends upon the operative procedure being performed

The bibliographic reference is:

1. Culver, D.H., et al., *Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System.* Am J Med, 1991. **91**(3b): p. 152s-157s.