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Major Article

Cost-effectiveness analysis of three methods of surgical-site infection surveillance: Less is more

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Decision- support

Background: A considerable proportion of surgical site infections (SSI) could be prevented by surveillance. The study aimed to compare the cost-effectiveness of 3 methods of SSI surveillance: Inpatient, phone, and out-patient clinic (OPC); to ensure that the risk of SSI is independent from loss-to-follow-up in phone and OPC surveillances, and to determine the reliability of phone surveillance.
Methods: A cohort of 351 surgical patients were followed by 3 different surveillance methods: inpatient, follow-up in OPC and over the phone. Costs of nurse time and phone calls were expressed in 2019 USD. Effectiveness of surveillance was assessed using number of detected SSIs.
Results: Phone surveillance was more cost-effective than OPC surveillance. Compared to inpatient surveillance, the OPC method costs USD 15.6 per extra detected SSI, whereas the phone method costs only USD 4.6

In phone and OPC surveillances, the risk of SSI was independent of loss-to-follow-up. However, the higher rate of SSI among OPC attendees raises the suspicion that the incidence of SSI estimated by OPC surveillance could be biased upward. Phone surveillance was reliable with high sensitivity and specificity.
Conclusions: Phone surveillance was a reliable cost-effective method. Inpatient surveillance was less effective, but it still can be used to detect severe SSI at low cost. While out-patient-clinic surveillance had the highest cost, the incidence estimated by it might be biased upward.

Up to 60% of surgical site infections (SSI) have been estimated to be preventable.[1,2]

Different methods are proposed for surveillance of SSI either inpatient or postdischarge. CDC recommended 2 methods to identify inpatients with SSIs; namely direct observation of the surgical sites, and indirect detection by infection control personnel. Postdischarge surveillance included: Examination of patients' wounds during follow-up visits, review of medical records, and patient surveys by mail or telephone.[3]

Postdischarge surveillance can detect more SSIs than that detected by inpatient surveillance as the majority of SSIs develop after hospital discharge.[4] However, the effectiveness of different postdischarge methods varies as well as their costs. Also, loss to follow-up (LTFU) is inevitable; and may lead to biased estimation if LTFU patients have different risk of SSI.[5] Moreover, reliability of the data collected by phone or e-mail is questionable[6] as they rely on patients as the source of information.

Therefore, this study was conducted to achieve the following objectives:

- Compare the cost-effectiveness of the following surveillance methods:
  - Inpatient surveillance: Indirect detection of SSI in the inpatients of surgery department
  - OPC surveillance: Direct observations of patients' wounds during follow-up visits in the OPC
  - Phone surveillance: Introducing postdischarge wound healing questionnaire on phone

Abbreviations: ASA PS Classification, ASA Physical Status Classification System; CDC, Center for Disease Control and Prevention; EGP, Egyptian pound; LTFU, lost-to-follow-up or loss to follow-up; MRI, Medical Research Institute; NNIS, National Nosocomial Infections Surveillance; OPC, outpatient clinic; SSI, surgical site infection; USD, United States Dollar.

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- Ensure that the LTFU was independent of the risk and incidence of SSI
- Examine the reliability of data collected by *phone surveillance*.

METHODS

Over a period of 26 weeks, we recruited a prospective cohort of 351 patients who underwent any surgical procedure in the free section of the MRI hospital; with exclusion of endoscopic, diagnostic procedures, and procedures where primary closure of the incision was not completed in the theater. Eight of them had bilateral surgeries.

Data collection

Data were collected by a staff member trained to undertake the SSI surveillance. Collected data were; patient operative data and SSI data

Patient operative data

- Surgical operation category, as proposed by the Public Health England for the surveillance of SSI.[7] Procedures not included were grouped into 4 categories according to their anatomical site and clinical similarity.
- Duration of postoperative hospital stay in days
- Laparoscopic-assisted procedure, (Yes/No)
- Pre-operative physical condition, measured by ASA PS classification score.[8]
- Degree of wound contamination, according to the National Research Council in the USA[9]
- Operative duration (Prolonged/Not prolonged) was considered prolonged if it exceeded a T point, where T point is the length of time that represent the 75th percentile for the procedures[10] conducted in the MRI for each operative category. Accordingly, 40 procedures (12.5%) were prolonged.
- NNIS risk index[11] is an index used to categorize patients into 4 main categories; each has similar risk of SSI. A point was added in case of: Contaminated or dirty wound, ASA score higher than 2, or prolonged operative duration. A point was subtracted whenever the procedure was completely laparoscopic. Risk index ranged from “M” (indicates minus 1), where no risk factors were present, and the procedure was laparoscopic, to 3.

SSI data

Inpatient surveillanc. Staff member regularly contacted wards’ staff and reviewed medical and nursing records, temperature, and treatment charts 3 times a week to identify signs and symptoms of SSI. This method detected SSIs developed during the postoperative hospital stay as well as severe SSI that required readmission.

OPC surveillance. Staff member attended the OPC for checking wounds of attending patients 3 times a week. Diagnosis of SSI was made by the attending surgeon according the criteria defined by CDC for surveillance purposes.[12] This method detected SSI developed after patient discharge among patients attended the OPC for wound care. Patients did not attend were reported as “LTFU from OPC surveillance”

Phone surveillance. Staff telephoned patients after their 30th postoperative day and asked them questions on the postdischarge questionnaire proposed by Public Health England for the surveillance of SSI.[7] If the patient did not reply, 2 other trials were made at different occasions before being reported as “LTFU for phone surveillance”. SSI was reported if any of the followings was met:

- Patient reported discharging pus and prescribed antibiotics for wound infection.
- Patient complained from at least 2 of: Pain, heat, redness or swelling and prescribed antibiotics for wound infection.
- Patient complained from at least 2 of pain, heat, redness, or swelling, and noticed the edges of any part of the wound gaped open.

To determine whether LTFU is independent from the risk of SSI, risk of SSI is compared across the following 3 groups:

- Group 1: Patients who were reached by both OPC and phone
- Group 2: Patients who were reached by phone only
- Group 3: Patients who were not reached by either OPC or phone

Group 3 is the LTFUs from phone, while the LTFUs from phone, while Group 2 and 3 are the LTFUs from OPC surveillance.

To test the reliability of phone surveillance, data collected by phone surveillance were tested against that verified either by OPC or inpatient surveillances. Ethical clearance was obtained from the Institutional Review Board of Medical Research Institute.

Cost-effectiveness analysis

Costs were estimated in Egyptian pound (EGP). All costs were inflated to 2019 prices and expressed in USD using an accepted cost converter based on purchasing power parities.[13] Time of data collection was valued at nurse hourly rate of USD 4.1. The cost of phone calls was USD 0.09 per minute.

The effectiveness of SSI surveillance was assessed using: The number of successfully followed surgical sites and the number of detected SSIs.

Incremental cost-effectiveness ratio was used to according to the recommendations made by the second panel on cost-effectiveness in health and medicine.[14] **ICER** shows the additional cost required to obtain additional benefit when switching from inpatient surveillance to either OPC or phone surveillance.

Statistical analyses were performed using SPSS Statistics 21. Chi-square test was used to compare categorical variables; either Fisher’s exact or Mont Carlo corrections were applied when required. Chi-square test with trend was used to compare the NNIS risk index. The 95% CI for the incidence rate was calculated according to Wilson procedure with a correction for continuity.[15] Tukey’s hinges were used to interpolate the exact location of quartiles[16] as finding the quartile could be difficult in small samples. Significance test results were quoted as 2-tailed probabilities and judged at the 5% level.

RESULTS

Inpatient surveillance

During the postoperative inpatient stay only 1 patient developed organ/space SSI. Three patients were readmitted because of deep SSIs (Fig 1). The incidence rate of SSI was 1.1%; (95%CI: 0.4%, 2.8%) (Fig 2).

The length of postoperative hospital stay was less than 2 days among 75% of patients (Mdn = 1, IQR = 1, Min = 0, Max = 15).

OPC surveillance

Around 72% (n = 254 patients with 260 SS) sought wound care in the OPC. Thirty-two patients had SSI; most of them were superficial or deep infections (13, 18 patients respectively) whereas only 1 suffered organ/space SSI (Fig 1). The mean time elapsed before SSI was 7.8 days (SD = 4.6, Min = 2, Max = 20). Incidence of SSI in the OPC was 12.3% (95% CI: 8.9%, 16.9%) (Fig 2).

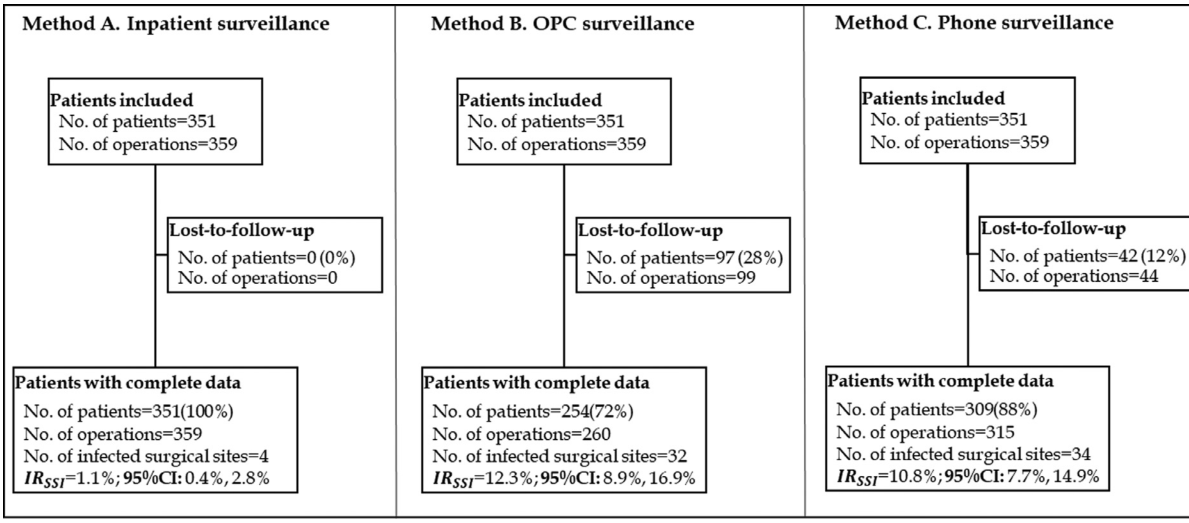

Fig 1. Flow chart for the loss to follow-up and the estimated incidence of SSI among the surveillance methods following a cohort of 351 surgical patients admitted to the MRI hospital over a 6-month period. *CI*, confidence interval; *OPC*, outpatient clinic; IR_{SSI}, incidence rate of surgical site infections.

Phone surveillance

Around 88% (n = 309 patients with 315 SS) could be reached by phone; 34 patients had SSI. Incidence of SSI by phone surveillance was 10.8% (95% CI: 7.7%, 14.9%) (Fig 2) Forty-two patients (12%) could not be reached by phone because either their phone numbers were wrong, or they did not reply.

Reliability of phone surveillance

Only one patient falsely reported no SSI on phone surveillance. The sensitivity and specificity of phone surveillance were 96.9% (95%CI: 83.8% to 99.9%) and 100% (95%CI: 98.4% to 100%), respectively. Consecutively, if a patient reported SSI on phone, then there is a high certainty that he/she actually having SSI (PPV = 100%; 95%CI: 88.8% to 100%). If a patient does not, the probability of no SSI (NPV) is 99.6%; [95%CI: 97.6% to 100%].

LTFU and risk of SSI

The LTFU from OPC surveillance was higher (28%) than that from phone (12%). NNIS risk index distribution was similar in patients successfully followed by phone and OPC (Group 1), by phone alone (Group 2), and LTFU patients (Group 3) (Table 1). Thus, there was insufficient evidence that LTFU patients had a different risk of SSI than that of successfully followed-up.

Rate of SSI was compared between OPC attendees and nonattendees (patients LTFU from OPC surveillance). Among OPC attendees (n = 254), 32 patients had SSI (12.5%). Among nonattendees (n = 55), 3 patients (5%) reported SSI, *P*-value was small ($X_1^2 = 2.3, P = .130$), yet did not reach statistical significance.

Cost-effectiveness of the three surveillance methods

The average weekly time needed for data collection was 30 minutes for inpatient surveillance (10 minutes 3 times a week); 4.5 hours for OPC surveillance (1.5 hours 3 times a week) and 1 hour for phone surveillance (20 minutes 3 times a week). A total of 910 minutes of phone calls were spent by phone surveillance (Table 2). Total cost was the highest for OPC surveillance (USD 479.4) and the least for inpatient (USD 53.4).

The least cost per successfully followed surgical site was USD 0.1 by inpatient surveillance; and the least cost per detected SSI was USD 5.5 by phone surveillance. Compared to inpatient surveillance, OPC method costs USD 15.6 per extra detected SSI, whereas phone surveillance costs USD 4.6.

Table 1
NNIS risk index of successfully followed and lost to follow-up patients admitted the Medical Research Institute hospital during the study period

NNIS risk index components	Group 1* (n = 254)		Group 2† (n = 55)		Group 3‡ (n = 42)		Test statistic (*P*-value)
Duration of surgery							$X^2 = 1.9$
>75th percentile	27	(11)	9	(16)	4	(10)	(.396)
Wound class							$X^2 = 1.1$
Contaminated or dirty	2	(1)	1	(.4)	1	(2)	(.764)
ASA							$X^2 = 3.4$
≥3	51	(20)	5	(9)	8	(19)	(.179)
Modified NNIS risk index							
M	30	(12)	10	(18)	4	(10)	$X^2_{trend} = 3.7$
0	160	(63)	34	(62)	29	(69)	(.712)
1	52	(20)	10	(18)	8	(19)	
2	12	(5)	1	(2)	1	(2)	

Values shown in the table are numbers and (%) unless otherwise is specified.
NNIS, National Nosocomial Infections Surveillance; *OPC*, outpatient clinic.
*Group 1: patients who were reached by both OPC and phone.
†Group 2: patients who were reached by phone only.
‡Group 3: patients who were not reached by either OPC or phoneGroup 3 is the lost-to-follow-ups from phone, while Group 2 and 3 patients are the lost-to-follow-ups from OPC.

Table 2
Cost-effectiveness of the surveillance methods for detection surgical site infection in the Medical Research Institute hospital during the study period

Cost-effective analysis	Inpatient surveillance	OPC surveillance	Phone surveillance
Cost			
Duration in minutes			
Nurse (min)	780	7,020	1,560
Phone (min)	0	0	910
*Cost due to nurse time (USD)	54.6	491.4	109.2
†Cost due to phone (USD)	0	0	100.1
‡Total cost (USD)	54.6	491.4	191.1
Effectiveness			
Successfully followed SS, *n*	359	260	315
Detected SSIs, *n*	4	32	34
§Extra cost (USD)	–	436.8	136.5
‖Extra detected SSIs, *n*	–	28	30
¶ICER of extra detected SSI (Extra cost/Extra detected SSI)	–	15.6	4.6

All monetary values are expressed in 2019 USD.
ICER, incremental cost-effectiveness ratio; *OPC*, out-patient clinic; *SS*, surgical sites; *SSI*, surgical site infections.
*The product of multiplying the time spent by the nurse in minutes by the unit cost of nurse minute (USD 0.07).
†The product of multiplying the number of phone minutes by the unit cost of phone minute (USD 0.09).
‡The sum of cost due to phone minutes and cost due to nurse time.
§The difference between the total cost of the surveillance and that of the inpatient surveillance.
‖The difference between the number of detected surgical site infection by the surveillance and that of the inpatient surveillance.
¶The result of dividing the extra cost by the extra detected SSIs.

Phone surveillance was more cost-effective than OPC in following surgical patients after discharge. In comparison to inpatient surveillance, both phone and OPC were more effective in detecting SSIs but at a higher cost. Meanwhile, phone surveillance was more cost-effective than OPC surveillance (Fig 2).

DISCUSSION

OPC surveillance was the least cost-effective due to the time needed for data collection as SSI data were not routinely reported in the OPC due to either time pressure and heavy workload, and lack of reporting obligations (Fig 3).

Phone surveillance was the most cost-effective although the least total cost was in inpatient surveillance, because the number of SSIs detected in inpatients was much lower than that detected by phone. The number of SSIs detected among inpatients depends on the length of postoperative hospital stay, which was less than 2 days in the majority of cases. Earlier discharge found in the current study is consistent with what was reported by others,[17-19] and might be explained by limited number of beds and shortage of staff.

The percentage of LTFU patients was 12% in phone surveillance. A similar rate (11%) was mentioned by Australian study in 2001.[20] This rate was considerably lower than that reported by earlier studies[21] and could be explained by the increase in telephone ownership over time.

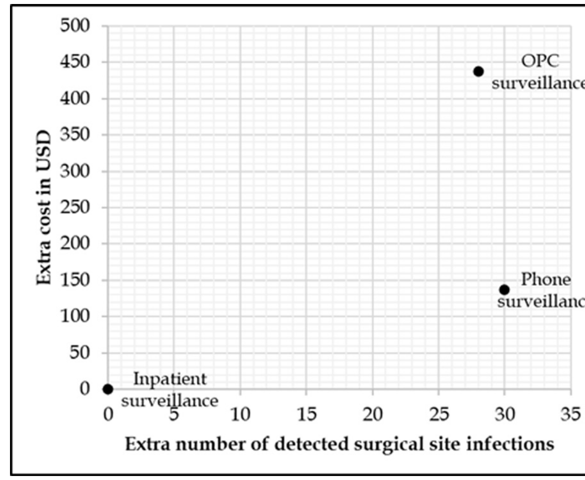

Fig 3. Cost-effectiveness plane of the surveillance methods following a cohort of 351 surgical patients admitted to the MRI hospital over a 6-month period. Extra cost (in 2019 USD) is displayed on the Y axis. Extra effectiveness is displayed on X axis. Inpatient surveillance is the reference case. Any surveillance method lies lower and to the right is more cost-effective. Both OPC and phone surveillances are more costly and more effective.

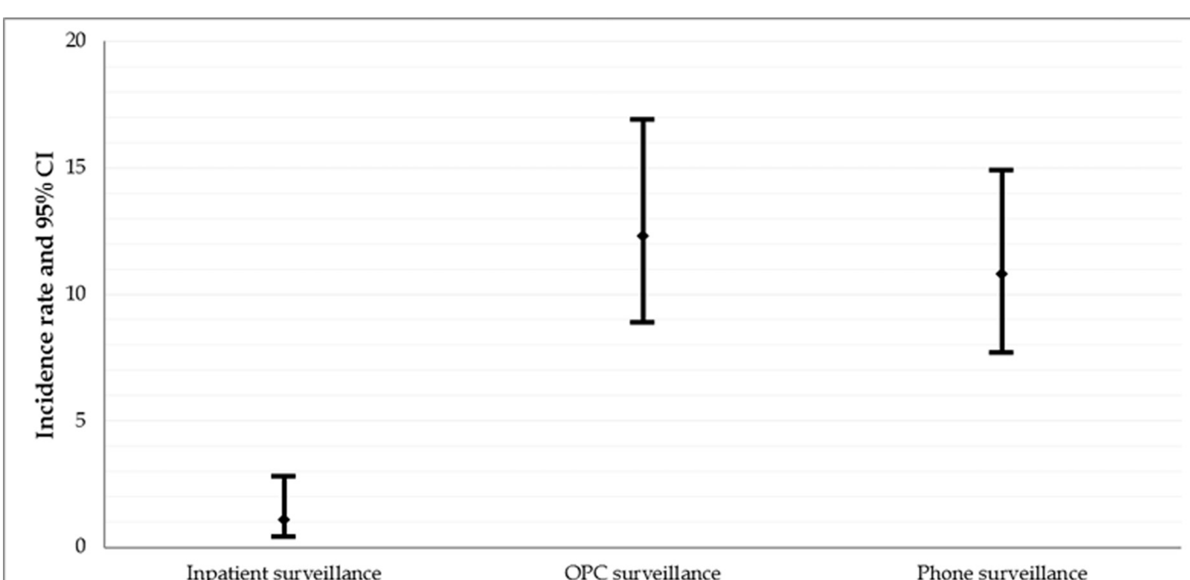

Fig 2. Error bar compares the incidence rate of SSI estimated by the 3 SSI surveillance methods following a cohort of 351 surgical patients admitted to the MRI hospital over a 6-month period

Phone surveillance showed no sufficient evidence that LTFU had different risk of SSI from those successfully followed. We believe that LTFU in case of phone surveillance are independent of patients' risk and could be attributed to wrongly reported or changed phone number.

Incidence of SSI among patients attended OPC was considerably higher than among nonattendees. Yet, this difference was statistically insignificant owing to the small number of LTFU. As studied patients were poor, they might be reluctant to seek treatment outside MRI while it is freely provided in the MRI hospital. Given the observed difference was considerable and the *P*-value was relatively small, the hypothesis that the incidence of SSI is higher among OPC attendants should be further investigated. If this hypothesis is proved to be true, then the incidence of SSI estimated by OPC surveillance is biased upward.

In the current study, phone surveillance data were highly reliable. This could be interpreted by the use of strict criteria for reporting.

Training on undertaking the surveillance is crucial to ensure the quality of data. Training required for phone surveillance is less challenging than that required for OPC; while, in OPC surveillance, the designated staff should be trained on diagnosing SSI according to CDC criteria[12]; he/she needs to be trained on only administering a set of clear questions in phone surveillance.

We believe that incidence rate estimated by phone surveillance is very close to the truth as percentage of LTFU was low, LTFUs were not significantly different from those successfully followed, and the reliability of data was high. Moreover, not only the cost in terms of time is much lower in phone surveillance, but the time and effort needed for training and the qualifications of the staff member designated to the surveillance is lower. While the accuracy of data collected by OPC surveillance is 100% as patients are directly observed, the higher rates of LTFU and of SSI among those attending the OPC raised doubts that the incidence estimated by OPC could be biased upward.

According to the results, adopting the phone surveillance is a cost-effective alternative to OPC surveillance. However, inpatient surveillance is still an option. Although it detected only 4 cases, it did detect the "important few "which were so severe that they occurred shortly postoperative or necessitate readmission. So, in resource shortage, allocation of money to the inpatient surveillance may be the only possible solution with 70% reduction in the total cost.

Our study has limitations. Regarding the rate of LTFU, our results cannot be generalized. The percentage of the LTFU varies dramatically in different settings. It is likely to be influenced by socioeconomic conditions, levels of education, population density, availability of transport, and population mobility.[22]

Another limitation is the use of the nurse's minute cost to value time to collect data. Skills needed to conduct the surveillances are not similar. In inpatient and phone surveillances, no need for training in examining surgical wounds and applying the definition of SSI; consequently, conducting inpatient or phone surveillance is not necessarily delegated to a well-trained nurse with higher salary. However, this limitation would not change our conclusion that phone surveillance is the most cost-effective methods.

Meanwhile, we achieved the goal of the study at the least effort and cost. We did not compare any of the surveillances to the "gold standard" SSI surveillance—a surveillance that follow all cases and detect all SSIs—as establishing such surveillance is improbable due to lack of resources. Also, we did not measure all resources needed to implement SSI surveillance (time needed for data acquisition in the operative department, or data checking), we only measured resources differed among the 3 surveillances.

CONCLUSIONS

Our study compared surveillance methods in terms of cost, rate of LTFU and proportion of detected SSIs in a developing country. It shows that, at every setting, costs and effectiveness of different surveillances should be examined before adopting any of them. While OPC surveillance was presumed accurate (diagnosed by hospital staff); systematic analysis revealed that phone surveillance proved to be more effective (in terms of percentage of followed and detected cases), highly accurate in estimating the incidence, and less costly.

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