Can a mobile app technology reduce emergency department visits and readmissions after lung resection? A prospective cohort study

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Presented at the Western Thoracic Surgery Association 44th Annual Meeting, June 27–30, 2018, Goleta, Calif.

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Accepted Feb. 15, 2022

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Cite as: *Can J Surg* 2022 November 23 65(6). doi: 10.1503/cjs.000122

Background: Emergency department (ED) visits and readmissions after thoracic surgery are a major health care problem. We hypothesized that the addition of a novel post-discharge mobile app specific to thoracic surgery to an existing home care program would reduce ED visits and readmissions compared to a home care program alone.

Methods: We conducted a prospective cohort study of patients undergoing major lung resection for malignant disease between November 2016 and May 2018. Patients received either home care alone (control group) or home care plus a patient-input mobile app (intervention group). Primary outcomes were 30-day readmission and ED visit rates. Secondary outcomes included reasons for ED visits and readmissions, perioperative complications, 30-day mortality, anxiety (assessed with the Generalized Anxiety Disorder-7 Scale [GAD-7]) and app-related adverse events. We compared outcomes between the 2 groups, analyzing the data on an intention-to-treat basis.

Results: Despite the greater number of open surgery and anatomic resections in the intervention cohort, patients in that group were less likely than those in the control group to visit the ED within 30 days of discharge (24.0% v. 38.8%, $p = 0.02$). Thirty-day readmission rates were similar between the intervention and control groups (10.1% v. 12.2%, $p = 0.6$). In a subset of patients, there was no difference between the 2 groups in the proportion of patients with a GAD-7 score of 0 (control group 79.8%, intervention group 79.5%, $p =$ NS), which indicated a similar absence of postdischarge anxiety and depression symptoms in the 2 cohorts.

Conclusion: The addition of a mobile app to a home care program after thoracic surgery was associated with a reduced frequency of ED visits, in spite of the higher proportions of thoracotomies and anatomic resections in the app cohort. More studies are needed to evaluate the full effect of this new, emerging technology.

Contexte : Les consultations aux urgences et les réadmissions après une chirurgie thoracique sont d'importants problèmes de santé. Selon notre hypothèse, l'ajout d'une nouvelle appli pour appareil intelligent à un programme existant de soins à domicile spécifique à la chirurgie thoracique, réduirait les consultations aux urgences et les réadmissions, comparativement au programme de soins à domicile seuls.

Méthodes : Nous avons procédé à une étude de cohorte prospective auprès d'une population soumise à une résection pulmonaire majeure pour cancer entre novembre 2016 et mai 2018. Le groupe témoin recevait les soins à domicile seuls et le groupe sous intervention recevait les soins à domicile en plus de l'appli. Les paramètres principaux étaient la réadmission à 30 jours et les taux de consultations aux urgences. Les paramètres secondaires incluaient les motifs de consultations aux urgences et de réadmissions, les complications périopératoires, la mortalité à 30 jours, l'anxiété (mesurée au moyen de l'échelle GAD-7 [General Anxiety Disorder-7]) et les effets indésirables liés à l'utilisation de l'appli. Nous avons comparé les paramètres des 2 groupes et analysé les données selon l'intention de traiter.

Résultats : Malgré le nombre plus élevé de chirurgies ouvertes et de résections anatomiques dans le groupe soumis à l'intervention, les membres de ce groupe étaient moins susceptibles de consulter aux urgences dans les 30 jours suivant leur congé (24,0 % c. 38,8 %, $p = 0,02$). Les taux de réadmission à 30 jours ont été similaires entre les 2 groupes (10,1 % c. 12,2 %, $p = 0,6$). Pour un sous-groupe, on n'a noté aucune différence entre les 2 groupes pour ce qui est de la proportion de patients ayant présenté un score GAD-7 de 0 (groupe témoin 79,8 %, groupe soumis à l'intervention 79,5 %, $p =$ NS), ce qui indique une absence similaire de symptômes d'anxiété et de dépression consécutifs au congé dans les 2 groupes.

Conclusion : L'ajout d'un appli pour téléphone intelligent à un programme de soins à domicile après une chirurgie thoracique a réduit le nombre de consultations aux urgences, malgré une proportion plus grande de thoracotomies et de résections anatomiques dans le groupe bénéficiant de l'appli. Il faudra procéder à d'autres études pour mesurer le plein effet ce cette nouvelle technologie émergente.

Hospital readmissions and emergency department (ED) visits after major thoracic surgery are common and carry a significant burden to the health care system.[1–4] Up to 14% of surgical patients are readmitted to hospital within 30 days, and, in the United States, 4.5 million patients experience unplanned readmissions annually, at a cost of about US$44 billion.[5] In thoracic surgery, 10%–17% of patients are reported to be readmitted after major lung resection, with higher rates expected in patients with multiple comorbidities and in-hospital complications.[2–4,6–9] Readmission after surgical resection for lung cancer has been associated with worse patient outcomes and a sixfold increase in mortality.[6–15]

In an effort to improve patient care after discharge from hospital, the Division of Thoracic Surgery at St. Joseph's Healthcare Hamilton, McMaster University, Hamilton, Ontario, designed and initiated the Integrated Comprehensive Care (ICC) program in 2013. This program is a home care initiative led by nurse navigators embedded within the hospital team. The team initially assesses patients who have undergone thoracic surgery immediately postoperatively while still in hospital, and then coordinates appropriate home care services, continuing to provide care for up to 60 days after discharge. In comparison to most generic home care programs, the ICC program uses allied health care members who are comfortable and experienced with patients who have undergone thoracic surgery, with the nurse navigator coordinating the care in the community and keeping a direct link with the hospital team as needed. In comparison to historical institutional controls, the addition of the ICC program (for all patients, regardless of their provenance from rural or nonrural areas) resulted in lower readmission rates and ED visits within 60 days of discharge.[16] As a result, the Ontario Ministry of Health approved the expansion of the ICC program regionally as well to other groups, and it became part of the standard of care after thoracic surgery at McMaster University.

This positive experience prompted us to look into additional ways to further improve postdischarge care and outcomes for patients undergoing thoracic surgery. Although the ICC program was associated with a shorter length of hospital stay, fewer readmissions, fewer ED visits and cost savings,[16] there continued to be gaps in detecting and monitoring complications, and so there were further postdischarge complications, ED visits and readmissions that could potentially be avoided. As such, there was a need for a new, innovative solution to support and monitor patients following their hospital discharge after thoracic surgery. There is emerging evidence, mostly in internal medicine and cardiology, that interventions to improve the transition from hospital to postdischarge care resulted in a reduction of readmission rates by 30%–50%.[17,18] These care pathways are varied, yet many interventions successfully prevent both unplanned and all-cause readmissions.[14] Costantino and colleagues[19] reported that an intervention as simple as support via telephone to patients and caregivers resulted in a significant reduction in readmission and ED visit rates.

Advances in mobile technology and applications are becoming increasingly popular and integrated into the care of both medical and surgical patients. The increased demand for mobile medical apps led the US Food and Drug Administration (FDA) to publish a guidance report to define which of these tools and devices should be eligible for FDA regulations.[20] Some of these apps involve a preventive approach to improve the care of patients in the outpatient setting[21–24] while attempting to decrease the misuse of resources and avoidable ED visits. These mobile apps have been used for a wide range of medical and surgical populations. This is especially important during recent adaptation of earlier discharge and recovery after surgery with increasing implementation of Enhanced Recovery After Surgery protocols.[25–28] In addition, patients are becoming increasingly interested in participating and being involved in their own care, and the use of personal apps helps support that interest. Some investigators have focused on the feasibility of use of a postdischarge mobile health app; however, to date, such an intervention has not yet been systematically evaluated in thoracic surgery.[29–32]

We therefore developed, in collaboration with SeamlessMD, a postdischarge mobile app specific to thoracic surgery to be used by patients and families at home to provide support through the initial postdischarge phase. We hypothesized that the use of the app, as an adjunct to our pre-existing ICC program, would result in lower readmission rates and fewer ED visits compared to the ICC program alone by facilitating timely and effective feedback between patients and the medical team so that problems can be identified earlier, thereby preventing postdischarge complications.

Methods

Mobile application

The mobile app comprises educational resources, personalized self-care reminders such as follow-up appointments and prompts to complete daily exercises, and a daily symptom check survey. The survey is a key feature of the app, as patients regularly report their status on a several domains such as fever, pain, edema in the lower extremities and reddened incisions. Patients record their survey responses on a user dashboard monitored by the ICC nurse daily, with concerning symptoms generating an automatic alert that will trigger immediate outreach by the nurse coordinator to the patient. Once contacted, the ICC nurse discusses the event that triggered the alarm with the patient and then provides advice, arranges for prescriptions if needed or schedules earlier reassessments with the most appropriate care provider, including referral to the ED if necessary.

Study design, participants and outcomes

This was a prospective cohort study. It was designed as a pre–post study, as the ICC program became a standard of care in our centre as of November 2016. All patients aged 19 years or more undergoing lung resection for malignant disease at St. Joseph's Healthcare Hamilton and discharged home postoperatively between November 2016 and May 2018 were eligible for the study. Patients were screened preoperatively for eligible surgical procedures and pre-existing home care arrangements. Eligible patients interested in participating in the study provided consent during their preoperative clinic visit, after providing consent for surgery. Exclusion criteria were having regular home care services separate from the ICC program for day-to-day care, nonenrolment in the ICC program, and having no daily access to an Internet-enabled computer, smartphone or tablet.

Patients were assigned to the ICC-based home care group (control group) until October 2017, and to the home care plus mobile app group (intervention group) thereafter.

Data on type of surgery, preoperative demographic characteristics and comorbidities, postoperative complications (scored according to the Ottawa Thoracic Morbidity and Mortality Classification System[33]) and date of discharge from hospital were collected prospectively. All patients were followed for 30 days after discharge, with outcome data collected by trained research staff at follow-up visits 2–4 weeks after discharge. All patients followed institutional in-hospital care pathways, and recovery was assessed by surgical staff in outpatient follow-up clinics 2–4 weeks and 3 months after hospital discharge with chest radiography and physical examinations.

Primary outcomes were 30-day ED visits and hospital readmissions. Secondary outcomes included reasons for ED visits and readmissions, perioperative complications, 30-day mortality, patient anxiety (as assessed with the Generalized Anxiety Disorder-7 Scale [GAD-7][34]) and app-related adverse events. The GAD-7 was administered to assess whether the introduction of the app resulted in increased anxiety or added stress for patients. We identified all regional and out-of-region hospital readmissions and ED visits from the institutional Local Health Integration Network integrated database. Readmissions and ED visits were identified within 30 days after the index hospital discharge by review of the ICC hospital-based database and by direct reporting through the ICC coordinator.

The study was approved by the Hamilton Integrated Research Ethics Board (2016–1899). It is reported in accordance with the TREND statement.[35]

Statistical analysis

We analyzed the data on an intention-to-treat basis. We compared parametric continuous variables using Student *t* tests, and nonparametric variables with Wilcoxon rank-sum tests. We used χ^2 tests for categoric and nonparametric variables. We performed multivariable logistic regression to determine whether differences in patients' demographic characteristics and comorbidities, the type and extent of resection, and open versus minimally invasive (robotic or video-assisted thoracic surgery) procedures affected the number of ED visits or readmissions. In light of observed differences in patient and surgical characteristics evident between the groups, we performed post hoc propensity matching as a sensitivity analysis to assess the stability of the observations regarding ED visits noted in the univariable and multivariable analyses.

RESULTS

Between November 2016 and May 2018, 601 patients underwent lung resection for malignant disease at our institution (Figure 1). Of the 601, 398 were enrolled, 121 in the intervention group and 277 in the control group. Figure 1 shows the reasons for exclusion for the 203 patients who were screened for participation but were not enrolled (largely language barriers, lack of access to appropriate technology and involvement in other studies at our institution).

Patient characteristics were largely similar across the 2 cohorts, with the exception of the mean percent postoperative predicted diffusing capacity of the lung for carbon monoxide (control group 70.8% [standard deviation (SD) 20.23%], intervention group 78.1% [SD 16.52%], p = 0.005) (Table 1). The rate of minimally invasive surgery was lower in the intervention group than in the control group (56.2% v. 67.2%, p = 0.04), as was the rate of less invasive procedures such as wedge resection (17.4% v. 28.4%, p = 0.02). The incidence of lobectomy was higher in the intervention group than in the control group (66.9% v. 51.4%, p = 0.004). The median length of stay was similar between the 2 groups (3.66 d for the intervention group v. 4.05 d for the control group, p = 0.2).

Follow-up was complete for all patients. There were no deaths in either group by 30 days after surgery, and no adverse events due to nonuse, wrong use or overuse of the mobile app were identified. Readmission rates within 30 days of discharge were not significantly different between the intervention and control groups (10.1% v. 12.2%, p = 0.6), whereas the number of ED visits within 30 days of discharge was lower in the intervention group than in the control group (24.0% v. 38.8%, p = 0.02). There was no difference in the rate of multiple ED visits between the 2 groups (4.4% for the intervention group v. 12.2% for the control group, p = 0.4).

On univariate regression analysis, lobectomy was associated with rates of ED visits and readmission. More patients in the control group than in the intervention group were seen in the ED for dyspnea (4.3% v. 2.5%), weakness (2.9% v. 0.8%) and poor pain control (5.0% v. 2.5%)

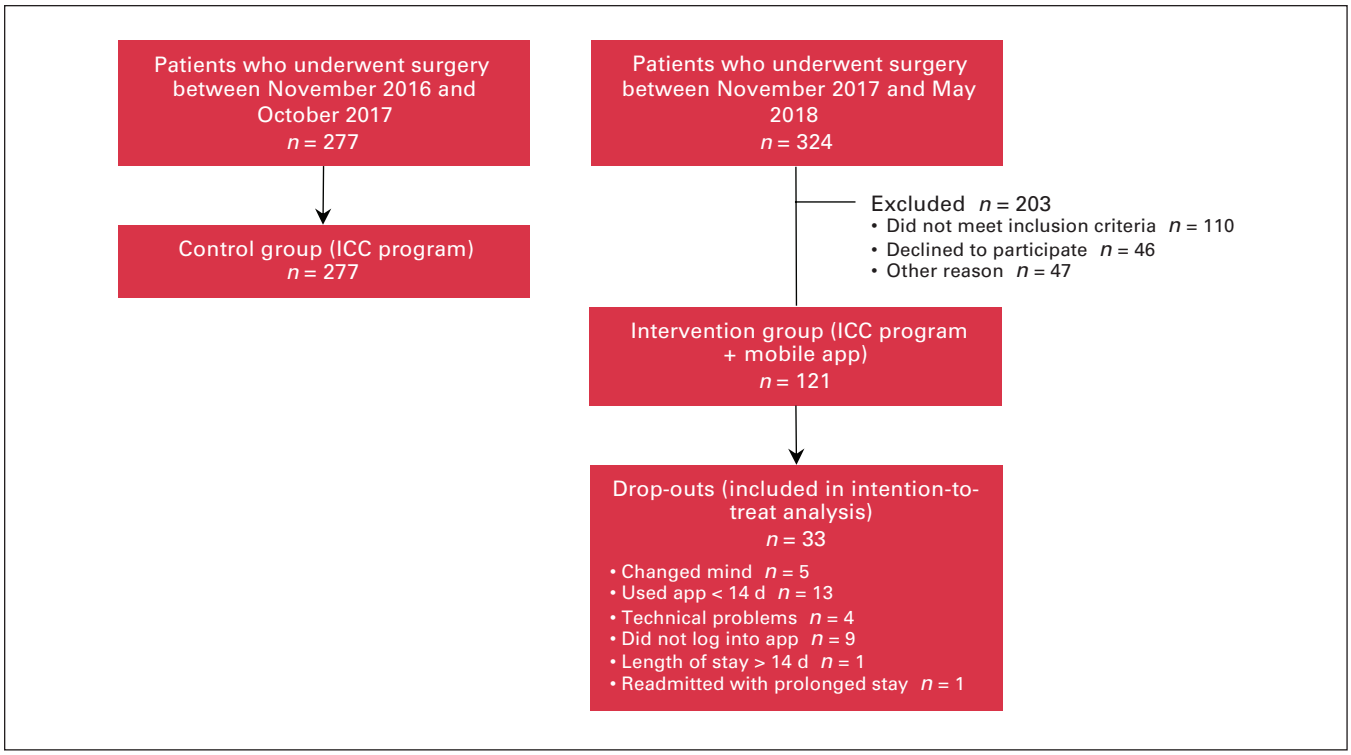

Fig. 1. Flow diagram showing patient allocation. ICC = Integrated Comprehensive Care.

(Figure 2A). Reasons for readmission, mostly pulmonary related, were similar between the 2 groups (Figure 2B) in spite of a higher rate of anatomic resection and a lower rate of minimally invasive surgery in the intervention group than in the control group.

Given the preliminary differences between the groups in type and extent of resection, we performed a multivariable regression analysis, which showed that mobile app use was the only independent predictor of a lower rate of ED visits. Propensity matching created 2 matched groups for the intervention (n = 52) and control (n = 138) groups. Analysis of the matched groups showed a persistent trend toward an association between fewer ED visits in the intervention group than in the control group (17.3% v. 26.9%, T-stat = –0.9), although it was not statistically significant. As a post hoc test, this exploratory analysis was not adequately powered to answer that specific point.

A nonselected subgroup of patients (47 [38.8%] in the intervention group and 101 [36.5%] in the control group, p = 0.6) were contacted by a trained research assistant and completed the GAD-7. There was no difference in the proportion of patients with a GAD-7 score of 0 (control group 79.8%, intervention group 79.5%, p = NS), which indicated a similar absence of postdischarge anxiety and depression symptoms in the 2 cohorts.

Table 1. Patient demographic and clinical characteristics for the control (no app) and intervention (app) cohorts

Characteristic	Group; no. (%) of patients*	
	Control n = 277	Intervention n = 121
Age, mean ± SD, yr	65.9 ± 12.46	66.5 ± 9.33
Male sex	140 (50.5)	49 (40.5)
Minimally invasive approach	186 (67.1)	68 (56.2)
Resection type		
Lobectomy	142 (51.3)	81 (66.9)
Wedge resection	79 (28.5)	21 (17.34)
Segmentectomy	26 (9.4)	16 (13.2)
Pneumonectomy	8 (2.9)	3 (2.5)
Smoker	196 (70.8)	94 (77.69)
Comorbidities		
Diabetes mellitus	53 (19.1)	18 (14.9)
Cardiovascular disease	13 (4.7)	1 (0.8)
Chronic kidney disease	8 (2.9)	2 (1.6)
Liver disease	6 (2.2)	0 (0.0)
% predicted FEV_1, mean ± SD	83.09 ± 21.05	88.38 ± 22.02
% predicted DLCO, mean ± SD	70.8 ± 20.23	78.1 ± 16.52
Length of stay, median, d	4.05	3.66

DLCO = diffusing capacity of the lung for carbon monoxide; FEV_1 = forced expiratory volume in 1 second; SD = standard deviation.
*Except where noted otherwise.

Patient surveys in the intervention group

Surveys were completed by 85 participants (70%). Most patients (79 [93%]) reported using the mobile app at least once. More than half of patients (48 [56%]) used their desktop/laptop computer for the app, and 10 (12%) and 11 (13%) used a tablet or mobile phone, respectively; the remaining patients did not respond to this question. Of the 85 patients, 62 (73%) reported using the educational

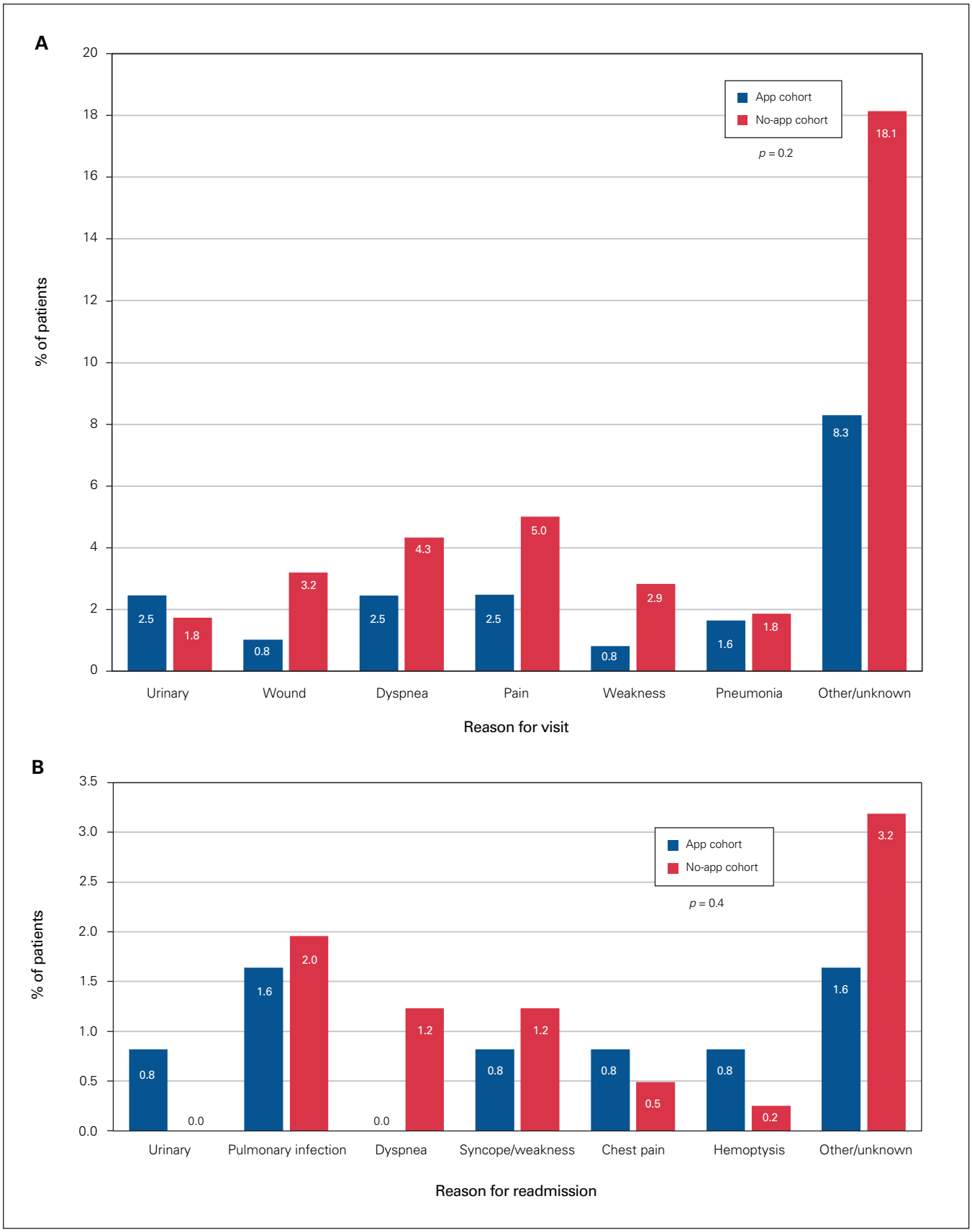

Fig. 2. (A) Reasons for emergency department visits within 30 days after surgery. (B) Reasons for hospital readmissions within 30 days after surgery.

resources provided on the app website, 77 (91%) indicated a high level of confidence in their ability to use the app, and 66 (78%) agreed or strongly agreed that the app played an important part in their postdischarge care. Seventy-five patients (88%) indicated that the use of the mobile app saved them from going to their family doctor or the nearest ED.

Discussion

In this article, we report our initial experience with the addition of a novel mobile app to an existing integrated home care program for patients undergoing lung resection at our institution. Our results favour the use of the app in that we observed lower rates of ED visits in the initial 30 days after discharge from hospital in the intervention group than in the control group despite the higher proportion of patients with open surgery as well as more complex resections (more lobectomies and fewer wedge resections) in the former. This suggests that the patients in the intervention group were potentially more predisposed to requiring postdischarge attention and to experiencing additional ED visits and eventual readmissions. Readmission rates, however, were similar between the 2 groups, which likely indicates that a certain proportion of patients will ultimately be readmitted to hospital after thoracic surgery, likely secondary to pre-existing comorbidities, complexity of the surgical intervention and perioperative complications. The finding of similar readmission rates also indicates that many visits to the ED are potentially avoidable, as they do not lead to an eventual readmission; they should instead be dealt with through an out-of-hospital intervention. It is possible that the ICC program with the addition of the mobile app enabled additional support and communication to address minor issues such as postoperative pain and wound care, and to safely address less concerning symptoms in clinic or even over the telephone, avoiding unnecessary ED visits for these patients.

The overall ED visit rates observed in our study are higher than those reported in the literature.[15,36] There are several reasons why this may be. One reason may be the relatively short length of stay for our patients (median 3 d), as there is a trend toward earlier discharge from hospitals after lung resection. One of the strengths of the ICC program is that we have more knowledge of our patients' clinical course after discharge and are likely capturing more ED visits and readmissions through the program, as well as through the prospective database collected and maintained by our nurse coordinator. As such, there is a lower risk of missing outcome events than with other forms of data collection.

Limitations

Our sample was relatively small, and, thus, the power of our conclusions may be limited. This is particularly relevant while trying to analyze reasons for postoperative ED visits and readmissions, where the small number of events may preclude meaningful statistical analysis. The nonrandomized nature of the study exposes the groups to a strong selection bias. However, we performed a multivariable regression analysis to compensate for this limitation and found that the use of the mobile app was the only variable that contributed to reduction in ED visits; thus, the impact of nonrandomization is likely minimal. It is also possible that presenting new technology in a study may independently create a selection bias, attracting more patients who are comfortable with the technology. There were a number of patients who did not use the app after discharge from hospital or used it only for a short period. These patients were nonetheless included in the intervention group statistics as per the intention-to-treat analysis, and although this likely diminished the power of the analysis somewhat (likely in favour of the control cohort), this is also reflective of real-world use outside a strict study protocol, and so the results likely are more applicable to true app use. Although we administered the GAD-7 only to some of our patients, we believe this gave us important information that will assist in designing a larger, prospective trial to assess the full effect of mobile device use in the postoperative setting, particularly in the COVID-19 era. Finally, as our centre already has a well-structured postdischarge program (the ICC program) looking after patients while still in hospital and later at home, it is possible that the effect of adding mobile app technology after discharge may be more prominent in centres where such a program does not exist. A prospective cohort study comparing our centre to similar centres without a pre-existing program might capture the overall effect of both interventions (ICC program and mobile app).

Conclusion

Our preliminary study, in spite of several limitations inherent to such a preliminary analysis, showed that the use of mobile app technology was associated with a significant reduction in postdischarge ED visits, no changes in readmission rates and no adverse events related to its use. More studies are needed to evaluate the full effect of this new, emerging technology.

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Competing interests: Waël Hanna reports a grant from Intuitive Surgical, consulting fees from Minogue Medical, and payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events from Minogue Medical and AstraZeneca. He participates on an advisory board for Roche Genentech. He holds stock or stock options in Intuitive Surgical. No other competing interests were declared.

Contributors: W. Hanna, J. Agzarian and C. Finley designed the study. J. Taylor, K. Hughes, P. Pinkney, Y. Lopez-Hernandez, M. Coret, L. Schneider, J. Rushton and A. Tran acquired the data, which F. Minervini and Y. Shargall analyzed. F. Minervini, J. Taylor, K. Hughes, Y. Lopez-Hernandez and L. Schneider wrote the manuscript, which W. Hanna, J. Agzarian, P. Pinkney, M. Coret, C. Finley, J. Rushton, A. Tran and Y. Shargall critically revised. All authors gave final approval of the article to be published.

Disclaimer: This evaluation of the mobile application was developed independent of SeamlessMD, which had no influence on the study design, interpretation or conclusions.

Funding: This work was funded by the Mortgage Intelligence/GMAC Residential Funding of Canada Chair in Thoracic Surgery, held by Yaron Shargall.

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