



S128: Active post discharge surveillance program as a part of Enhanced Recovery After Surgery protocol decreases emergency department visits and readmissions in colorectal patients

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Abstract

Background Enhanced Recovery After Surgery (ERAS) programs aim to standardize perioperative care to reduce morbidity and cost. Our study examined an Active Post-Discharge Surveillance (APDS) program in reducing avoidable readmissions and emergency department (ED) visits in postoperative colorectal ERAS patients.

Methods Colectomy (right, subtotal and total) and low anterior resection cases performed at a tertiary care hospital between 2015 and 2018 were reviewed. ED visits, 30-day readmissions, and patients' APDS participation were assessed. Our APDS followed a modern text messaging paradigm offered to all patients free-of-charge.

Results Of 236 patients that underwent colectomy, 123 utilized APDS and 113 did not. Overall, both non-surveillance (NS) and active surveillance (AS) groups had similar preoperative characteristics. Length of hospital stay at index surgery was longer in the NS compared to AS group, 4.7 ± 2.6 vs. 2.6 ± 2.8 days, respectively ($p < 0.001$). In the NS group, 16 patients visited the ED, of which 14 (14/16, 87.5%) were ultimately readmitted. One patient was directly readmitted from the surgeon's office, resulting in a total of 15 (15/113, 13.3%) total patients readmitted by postoperative day (POD) 30. In the AS group, 9 patients visited the ED, of which 7 (7/9, 77.8%) were ultimately readmitted. One patient was directly readmitted, resulting in a total of 8 (8/123, 6.5%) total patients readmitted by POD 30. AS patients had significantly lower odds of visiting the ED when compared to NS patients (OR: 0.356; 95% CI: 0.138–0.919; $p = 0.0328$). Similarly, AS patients had significantly lower odds of readmission when compared to NS patients (OR: 0.343; 95% CI: 0.132–0.892; $p = 0.0283$).

Conclusions APDS allows many postoperative issues to be resolved in outpatient settings without ER visits or readmission. This indicates APDS is a valuable ERAS adjunct by establishing a cost-effective and convenient communication line between patients and their surgical team.

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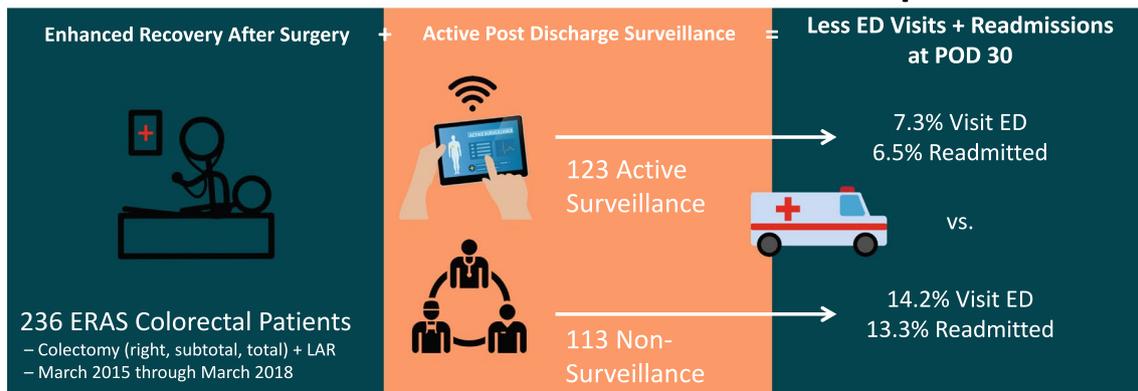
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Graphical abstract

Active post discharge surveillance program lowers ED visits and readmissions for ERAS colorectal patients



Keywords Active surveillance · Avoidable · Emergency department visits · Readmissions · ERAS

Avoidable postoperative emergency department (ED) visits and consequent readmissions are an issue endemic to healthcare systems across the world [1–5]. As a result of these encounters, EDs are overwhelmed, straining valuable resources that could be otherwise allocated to higher priority emergency cases, thus adding to the increasing costs of healthcare [1, 3, 4, 6, 7]. Furthermore, with the implementation of Enhanced Recovery After Surgery (ERAS) programs, patients are being discharged earlier. However, avoidable ED visits and readmissions are potentially offsetting the benefits gained by early hospital discharge [3, 8].

Fortunately, with the growing availability and simplicity of technology and communication platforms, the medical field has begun to modernize telemedicine to address these issues [9]. Modern telemedicine describes the provision of clinical healthcare from a distance and mitigates this issue of unnecessary encounters [9]. A form of telemedicine that involves asynchronous image sharing has proven successful for follow-up and clinical assessment for burn care, dermatology, and plastic surgery patients [9]. Active post-discharge surveillance (APDS) applications for mobile devices represent a promising iteration of telemedicine that allows patients and physicians to communicate securely and directly [7, 10, 11]. Data have shown these mobile applications provide timely detection of postoperative complications, less time spent answering phone calls by the surgical team, and low (0.9%) emergency (ER) visit rates [6].

Nevertheless, the visual component is frequently lacking in existing telemedicine platforms, which might explain the low satisfaction rates of both surgeons and patients, as well as the lack of patient compliance [10, 11]. A study by the University

of Wisconsin–Madison investigated the benefits of utilizing an image-based mobile communication platform for postoperative wound monitoring [11]. They reported high overall user satisfaction (83%) with the mobile application and high remote diagnostic accuracy (82%) based on the wound images sent by patients from home [11].

However, to date, studies that investigate the effect of telemedicine in relation to ED visits and readmission in ERAS colorectal surgery patients are lacking. The aim of our study is to examine the impact of an active post-discharge surveillance (APDS) program on 30-day postoperative emergency room visits and readmissions in colorectal surgery patients having undergone the ERAS protocol.

Materials and methods

Study population

Institutional review board approval was obtained prior to data collection and analysis. A retrospective chart review was conducted at a tertiary care hospital. Right hemicolectomy, subtotal colectomy, total colectomy, and low anterior resection (LAR) cases of four colorectal surgeons between March 2015 and February 2018 were included in the review. All patients included in the review underwent the Enhanced Recovery After Surgery (ERAS) protocol.

ERAS/PSH (perioperative surgical home)

The ERAS protocol implemented at our institution is used in the context of the American Society of Anesthesiologists

(ASA) perioperative surgical home (PSH) initiative to form an ERAS/PSH multidisciplinary team. This team involves members from 22 different departments such as administration, pharmacy, nursing, and the colorectal surgeons. In our institute, the ERAS/PSH was first implemented in August 2014 and reached full functionality (sans active surveillance) in March 2015. Implementation of the APDS program began a year later, in March 2016, with the colorectal service. In the first 9 months following APDS implementation (March 2016 – November 2016), minor adjustments to the surveillance algorithms were made as a part of our institution's learning curve. These dates determined the time spans of cases selected for retrospective review (Fig. 1).

Key elements in our ERAS program include: preoperative nutrition optimization, non-narcotic pain control, minimization of intravenous (IV) fluid administration, wound care, timely discharge planning, and APDS. While these elements were implemented in different phases, the APDS program primarily comes into play post-discharge.

ADPS program

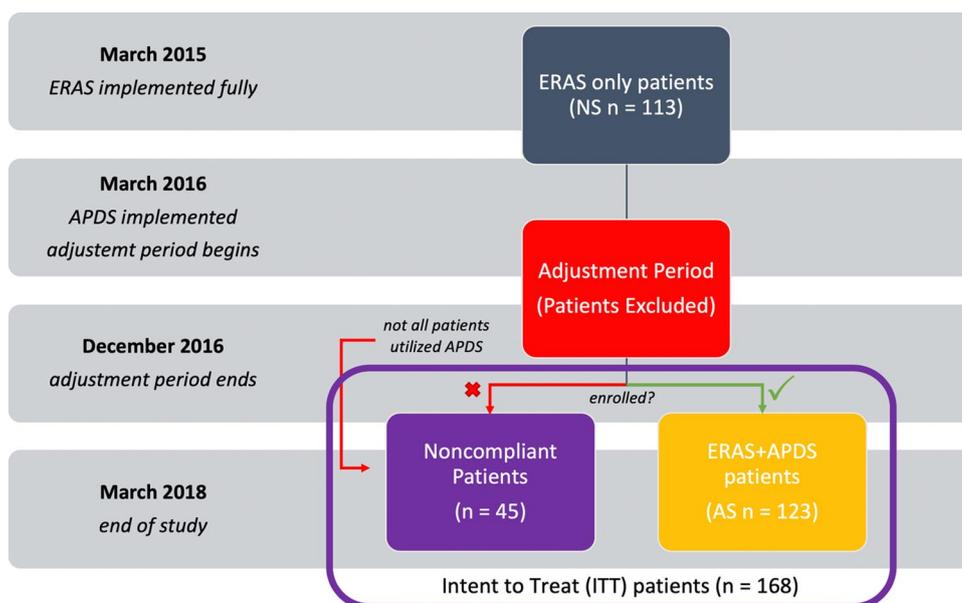
Following introduction of the APDS program to the colorectal service, all patients are offered the opportunity to enroll in the program prior to undergoing surgery by a PSH nurse in the preoperative clinic as part of our institution's ERAS protocol. Patients who have chosen to not enroll in APDS or have failed to complete their enrollment are offered the opportunity once again prior to their discharge from the surgical floor. Patients who are unable to utilize APDS themselves are encouraged to have their caretaker (typically a family member or home health nurse) use the application on their behalf. Our APDS

is offered systemwide to all ERAS patients at no cost to patients, regardless of their insurance status.

Twistle (Twistle Inc., Seattle, WA) is the quality improvement technology vendor that provided the APDS platform. The exact cost of the APDS was not available to us due to a confidential agreement between Twistle Inc. and our institution. However, the cost of the application constituted less than 1% of the total cost of all cases using the APDS, and was negligible relative to savings. The APDS is Health Insurance Portability and Accountability Act (HIPAA) compliant and primarily designed for smartphone use. The program's interface is centered on a modern text messaging paradigm. Patients, physicians, physicians' office staff, nurses, care coordinators, and extended care nurses can all communicate and coordinate care via the APDS platform on their smartphones or personal computer. For patients that do not have a smartphone, such as the elderly, low socioeconomic status (SES) patients, or sick patients who are unable to use a smartphone, the APDS program can be used by a caretaker proxy. The program can also be operated via email, a desktop computer, or over the phone using an automated system. Furthermore, the APDS program provided the opportunity for multilingual engagement with patients. Other than English, our version had support for two commonly spoken languages in our region: Spanish and Polish.

The program employs automated protocols defined by the surgery care team to automatically communicate with patients before and after surgery. Prior to surgery, the APDS would issue the patient alerts; for example, a reminder to use chlorohexidine wipes the day before surgery, accompanied by a video demonstrating proper use of the wipes. Following surgery, the APDS program actively

Fig. 1 Time spans of cases included in retrospective review and breakdown of study cohorts



surveilles patients with regard to condition of surgical site (soliciting pictures if necessary) and overall wellbeing via questionnaires (Fig. 2).

If the APDS program identifies that a patient's pre-rehabilitation or recovery might be off-track based on data gleaned from the patient questionnaires—or a lack of responses—it will notify the patient to take corrective action, alerting care team members to intervene as necessary. These alerts will then escalate to the surgeon either upon request of the patient or care team member, or via the automated protocol. The surgeon can then advise the patient appropriately via the mobile application or phone call. One plausible scenario is dehydration. If the APDS program determined a patient to be at risk of dehydration based on the patient's responses to questions about ostomy output and fluid intake, the program would educate the patient on dehydration. Moreover, the care team would receive an alert to engage the patient and, if necessary, follow through with an appropriate intervention.

APDS triage

Our APDS was primarily monitored by three groups: Colorectal Home Health nursing staff, the surgeons' office staff, and the surgeons themselves. Patient concerns and responses would be triaged by a home health registered nurse (RN). Once a concern would be elevated directly to the surgeon,

that concern would manifest in the form of a “conversation”—similar to a text message thread on a smart phone. This “conversation” would remain active until either the surgeon or patient would resolve said thread; however, the patient's connection to the care team would remain active following thread resolution. The surgeon could add an RN or office staff to the thread to help resolve the patient's concern. Any message sent through that conversation window would appear as a regular smartphone notification from the APDS application for all parties in that message thread.

No team member was on call with APDS. Despite this, if a patient's initial concern was not addressed by home health staff within three hours or sent outside of business hours (after 5 PM), the alert would automatically be escalated to the entire care team in the form of a notification. This would include the operating surgeon, designated office staff, and colorectal home health staff. If the surgeon was on vacation or unavailable, the message would then triage to the surgeon on call. If the patient requested phone follow-up, they would receive a call from a care team member. The following message confirming their call request would appear:

Thank you. A [Office staff, nurse, or surgeon; as selected by patient] will call you by the end of the business day. If this is not an emergency, and it is after 5 pm Monday–Friday or on a weekend, you will receive a call the next business day.

21:15 19%

Twistle Daily Check-in

Have any of the following occurred/changed in the past 24 hours?

A temperature above 100.4

Vomiting

Worsening nausea

Redness or pain around the incision site

None of the above

Do you have any questions or concerns that you would like someone to call you about?

No

Yes

Fig. 2 Visual of APDS daily patient questionnaire

Data collection and interpretation

Patient demographics, ED visits at or prior to postoperative day (POD) 30, and readmissions at or prior to POD 30 were collected. Assessed demographics included diagnosis, smoking status, neoadjuvant chemotherapy, patient disposition, stoma presence, and ASA score. Perioperative variables, including procedure type, surgical site infection (SSI), and length of stay (LOS), were also assessed. Patients were split into two cohorts prior to statistical analysis, non-surveillance (NS) and active surveillance (AS)—determined by the date of APDS availability. Cases that occurred between March 2015 and February 2016 were included in the NS group. Cases that occurred between December 2016 and February 2018 were included in the AS group.

Surgeries performed between March 2016 and November 2016 were excluded from the study. This 9-month period between the designation of NS and AS groups was excluded to account for the healthcare system adjusting to the implementation of active surveillance. During data collection, cases in the AS cohort were checked against APDS program records to ensure patient enrollment and engagement in the program. Failure of a patient to enroll in or interact with the APDS program resulted in the patient being excluded from the AS cohort; however, these patients remained in a third

intent to treat (ITT) super-cohort. This ITT cohort was comprised of all AS patients—compliant and non-compliant. This ITT cohort allowed for analysis of APDS in an intent to treat model. The AS cohort allowed for analysis of APDS in an as-treated model. (Fig. 1).

Additional exclusion criteria from the retrospective review included patients who were under 18 years of age, patients admitted for emergency surgery and thus unable to undergo the entire ERAS pre-surgical protocol, as well as patients who stayed at the hospital for longer than 30 days or were transferred to hospice care rather than discharged home or an extended care facility (ECF).

Outcomes and definitions

Charts of patients who visited the ED or readmitted at or prior to POD 30 were independently reviewed by two board-certified colorectal surgeons. These chart reviews were conducted for each patient encounter involving an ED visit, readmission, or both to classify and understand each patient's complication. Any disagreements were resolved by a third reviewer. All reviewers were blinded regarding patient participation in APDS.

The terms *avoidable* and *unavoidable* were used to designate postoperative ED visits on the basis of whether or not they could be potentially avoided with proper use of an APDS program. *Avoidable* ED visits and readmissions included: superficial SSI, constipation, psychiatric complaints (anxiety, depression), leakage around the surgical drain or from the wound, abdominal pain of unknown etiology, transient hematuria, mild hematochezia, uncomplicated urinary tract infection (UTI), bronchitis, allergic contact dermatitis, atelectasis, gastroenteritis, and *C. diff* infection without colitis. *Unavoidable* ED visits and readmissions included: deep SSI, organ space SSI, anastomotic leak, *C. diff* colitis, acute kidney injury, septic shock, small bowel obstruction (SBO) requiring surgical intervention, bleeding duodenal ulcers, and thromboembolic events.

Patients' diagnoses were then classified following their ED visit and, if applicable, readmission, as *minor* or *major* complications. Major complications included: anastomotic leak, *C. diff* colitis, space SSI, acute kidney injury, small bowel obstruction (SBO) requiring surgical intervention, bleeding duodenal ulcers, and thromboembolic events. Minor complications included: urinary retention, uncomplicated UTI, minor SBO, ileus, superficial SSI, pneumonia without respiratory distress, bronchitis, gastroenteritis, peristomal dermatitis, short duration pseudo-colonic obstruction, flare of colitis in the rectal stump, atelectasis, and *C. diff* infection without colitis.

The APDS data were also analyzed to determine how many patients were prevented from visiting the ED. These instances were denoted as a *save*. A *save* is defined as an

instance where an interaction between a patient and a health-care provider via APDS may have prevented that patient from going to the ED or being readmitted unnecessarily. These *saves* were independently determined by two board-certified colorectal surgeons. Disagreements were resolved by a third reviewer.

Statistical analysis

Bivariate analyses were conducted on patient demographic data to assess for any statistically significant differences in demographics between the NS and AS cohorts. For non-parametric, continuous patient data, Welch's t tests were performed. For categorical data, Chi-squared tests of homogeneity and Fisher's exact tests were performed. To compare ED visits and readmissions between the cohorts, binomial logistic regressions were used. The odds ratios of association between the two cohort pairs (ITT vs. NS and AS vs. NS) were assessed based on ED visits and readmissions at or prior to POD 30. The models were adjusted appropriately for imbalances between the distributions of patient demographic variables. Conditions to perform tests of significance were confirmed and met for all tests. A significance level of 0.05 was used for all tests ($\alpha=0.05$). All statistical analyses were performed using SAS 9.4 for Windows (SAS Institute Inc., Cary, North Carolina, USA).

Results

Patient demographics

Of the 281 patient charts reviewed, 168 patients were eligible for APDS and thus categorized into the ITT super-cohort (168/281, 59.8%). Of these 168 patients, only 123 patients properly utilized the APDS program and were categorized into the AS cohort (123/168, 73.2%). The remaining 45 patients were excluded from the AS cohort for either failing to enroll in the APDS program (38/281, 13.5%) or excluded for enrolling but never interacting with the APDS program (7/281, 2.5%). There were 113 patients who were categorized into the NS cohort (113/281, 40.2%) based off having undergone surgery prior to APDS implementation at our institution. (Fig. 1).

Both the AS and NS cohorts had similar preoperative baseline characteristics with respect to age (60.3 ± 13.8 years and 63.4 ± 14 years, respectively (mean \pm SD); $p=0.0830$), gender (52.03% and 59.29% females, respectively; $p=0.2623$), smoking status ($p=0.6233$), surgical approaches ($p=0.1474$), procedure underwent ($p=0.2805$), disposition ($p=0.2963$), neoadjuvant chemotherapy ($p=0.3276$), ASA classification ($p=0.3422$), and mean body mass index (BMI) ($p=0.0634$). (Table 1). The AS group, however, had

a greater number of patients with a stoma (17/123, 13.8%; $p=0.0297$) than the NS group. (Table 1).

Length of stay

The mean length of hospital stay (LOS) at index surgery was significantly longer in the NS group compared to the AS group (4.7 ± 2.6 vs. 2.6 ± 2.8 days, $p < 0.001$). Patients utilizing the APDS program went home, on average, 2.1 days earlier than patients not on surveillance. (Table 1).

Emergency visits

NS group

Within the 113 patients identified in the NS group, there were 18 ED visits recorded prior to POD 30. Of these, 14

patients visited the ED once and 2 visited twice for a total of 16 patients (16/113, 14.2%) (Table 2). The most common cause of ED visits was abdominal pain (7/27, 25.9%), followed by nausea and vomiting (N&V) (4/27, 14.8%), and postoperative fever (3/27, 11.1%). The remaining chief complaints are shown in Table 3.

AS group

Within the 123 patients identified in the AS group, there were 12 ED visits recorded prior to POD 30. Of these, six patients visited the ED once and three visited twice for a total of nine patients (9/123, 7.3%) visiting the ED following discharge (Table 2). The three most common causes for ED visits were postoperative fever (3/18, 16.7%), small bowel obstruction (3/18, 16.7%) and N&V (3/18, 16.7%) (Table 3).

Table 1 Patient demographics

Patient demographics ($n=236$)	NS ($N=113$)	AS ($N=123$)	p
Age mean (range), years	63.4 (22–90)	60.3 (18–93)	0.0830
Female n (%)	67 (59.3)	64 (52.0)	0.2623
Smoking n (%)			0.6233
Yes	11 (9.7)	17 (13.8)	
No	96 (85.0)	100 (81.3)	
Former smoker	6 (5.3)	6 (4.9)	
Disposition n (%)			0.2963
Home	77 (67.9)	95 (76.9)	
Home health	21 (18.9)	22 (18.0)	
Rehabilitation	2 (1.9)	0 (0)	
Skilled nursing facility	13 (11.3)	6 (5.1)	
Surgical approaches N (%)			0.1474
Laparoscopic	102 (90.3)	102 (82.9)	
Robotic	7 (6.2)	9 (7.3)	
Open	4 (3.5)	12 (9.8)	
Procedures n (%)			0.2805
Colectomy	0 (0)	4 (3.3)	
LAR	78 (69.0)	81 (65.9)	
RHC	29 (25.7)	29 (23.6)	
STC	6 (5.3)	9 (7.3)	
Neoadjuvant chemotherapy n (%)	2 (1.8)	3 (2.4)	0.3276
ASA Classification n (%)			0.3422
I	0 (0)	4 (3.3)	
II	78 (69.0)	81 (65.9)	
III	29 (25.7)	29 (23.6)	
IV	6 (5.3)	9 (7.3)	
Stoma n (%)	6 (5.3)	17 (13.8)	0.0297
Mean \pm S.D. LOS (range), days	4.7 ± 2.6 (1–18)	2.6 ± 2.8 (1–30)	<0.001
Mean \pm S.D. BMI (range), kg/m ²	28.4 ± 6.0 (15.8–47.4)	26.9 ± 5.9 (17.7–49.9)	0.0634

LAR low anterior resection, RHC right hemicolectomy, STC subtotal colectomy

Table 2 ED visits and readmissions among NS ($n=113$) and AS ($n=123$) groups

	NS ($N=113$) n (%)	AS ($N=123$) n (%)
ED visits (patients)		
No ED visits	97 (85.8)	114 (92.7)
Total # patients visiting ED	16 (14.2)	9 (7.3)
1 ED visit	14 (12.4)	6 (4.9)
2 ED visits	2 (1.8)	3 (2.4)
Readmissions (patients)		
No readmissions	98 (86.7)	115 (93.5)
Total # patients readmitted	15 (13.3)	8 (6.5)
1 readmission	14 (12.4)	8 (6.5)
2 readmissions	1 (0.9)	0 (0)

Table 3 Chief complaints among NS and AS groups

n	NS ($N=27$)	AS ($N=18$)
Abdominal pain	7	1
Bleeding from surgical site	1	1
Cardiac event (bradycardia, prolonged QTc on ECG)		1
Chest pain	1	1
Colitis	1	
Diarrhea and hematochezia	1	
Diverticulitis	1	
Generic postoperative complications		2
Lack of bowel movement	1	
Musculoskeletal pain		1
Nausea & vomiting	4	3
Pneumonia	1	
Postoperative fever	3	3
Psychomotor symptoms		1
Shingles	1	
Shortness of breath (SOB)	1	
Small bowel obstruction (SBO)	1	3
Syncope	2	
Transaminitis	1	
Urinary retention		1

Readmissions

NS group

Of the 18 NS group ED visits, 15 resulted in a readmission (15/18, 83.3%). One patient in the NS group did not visit the ED but was admitted directly to the surgical floor from the surgeon's office. This resulted in a total of 16 readmissions for the NS group prior to or on POD 30. Of these 16

readmissions, 1 was from the same patient; and thus, there were 15 patients readmitted (15/113, 13.3%) (Table 2).

AS group

Of the 12 AS group ED visits, 7 resulted in readmission (7/12, 58.3%). One patient in the AS group did not visit the ED but was admitted directly to the floor from the surgeon's office. This resulted in a total of eight readmissions. No patients were readmitted twice. The total number of patients readmitted was eight patients (8/123, 6.5%) (Table 2).

Major and minor complications

We found the total number of minor and major complications to be 18 and 17, respectively. The incidence of minor complications was lower in the AS group at 33.3% (6/18), and higher in the NS group at 66.7% (12/18). The incidence of major complications was also higher in the NS group at 58.8% (10/17), compared to 41.2% in the AS group (7/17). However, neither the major nor minor complications were found to be statistically significant between the AS and NS groups ($p=0.2511$ and $p=0.3883$, respectively). The most common major complications were acute kidney injury (4/17, 23.5%), organ space SSI (4/17, 23.5%), and thromboembolic events (3/17, 17.7%). The most common minor complications were minor small bowel obstruction (SBO) and ileus (4/18, 22.2%) and *C. diff* infection without colitis and gastroenteritis (4/18, 22.2%). (Table 4).

Avoidable and unavoidable encounters

Among the 236 patients, there were a total of 7 avoidable and 25 unavoidable encounters. Overall, the avoidable encounters varied; no two avoidable encounters resulted from the same cause.

There were 19 total encounters in the NS group. Of those, 4 NS group ED visits and readmissions (4/19, 21.1%) were classified as avoidable, had APDS been available to those patients. These four avoidable encounters were the result of superficial SSI, atelectasis, colitis flare up, and allergic contact dermatitis. The remainder of the ED visits and readmissions were unavoidable (15/19, 78.9%). These unavoidable visits were typically the result of SBO, acute kidney injury, thromboembolic events, and organ space SSI. (Table 5).

In the AS group, there were 13 total encounters. Of those, 9 (9/13, 69.2%) of the ED visits and readmissions were a result of major complications, and as such were unavoidable despite the availability of the APDS program. These unavoidable ED visits were often the result of major SBO and acute kidney injury. The remainder of the ED visits (4/13, 30.8%) were classified as avoidable, most often for

Table 4 Complication severity and counts

Major	NS	AS	
Anastomotic leak	1	1	
<i>C. diff</i> colitis		1	
Organ space SSI	2	2	
Acute kidney injury	3	1	
Bleeding duodenal ulcer	1		
SBO requiring surgical intervention		2	
Thromboembolic event (pulmonary embolism, SMV thrombosis, deep vein thrombosis)	3		
Total	10	7	$p=0.2511$
Minor	NS	AS	
Minor SBO / ileus	3	1	
Superficial SSI	1		
Respiratory issues (pneumonia, atelectasis, bronchitis)	2	1	
Peristomal dermatitis	1		
Constipation	1	1	
Urinary retention		1	
Uncomplicated UTI		1	
<i>C. diff</i> infection without colitis / gastroenteritis	3	1	
Seizures	1		
Total	12	6	$p=0.3883$

SSI surgical site infection, *C. diff* Clostridium difficile, SBO small bowel obstruction, SMV superior mesenteric vein, UTI urinary tract infection

conditions such as constipation, bronchitis, uncomplicated UTI, and urinary retention (Table 5).

APDS vs. No APDS: emergency department visits and readmissions

Intent to treat (ITT) analysis

When accounting for non-compliant patients through the ITT cohort, the ITT group had fewer patients (19/168, 11.3%) visiting the ED compared to the NS group (16/113, 14.2%). Upon completing bivariate analyses of ED visit patient demographics, we found that tobacco use (17.1% current users, $p=0.0085$), procedure type (45.7% LAR, $p=0.0035$) and ostomy status (74.3% no ostomy, $p=0.0205$) are imbalanced among those visiting and not visiting the ED. After adjusting for these variables, we found the odds of visiting the ED in the ITT group to be 0.493 times the odds (95% CI: 0.218–1.113) of the NS group visiting the ED, although these odds were not statistically significant ($p=0.0887$). (Table 6).

Similarly, the ITT group also had fewer readmitted patients (14/168, 8.3%) prior to or on POD 30 when

Table 5 Classification and counts of complications

Avoidable	NS	AS
Atelectasis	1	
Superficial SSI	1	
Allergic contact dermatitis	1	
Colitis flare up in the rectal stump	1	
Constipation		1
Bronchitis		1
Uncomplicated UTI		1
Urinary retention		1
Total	4	4
Unavoidable	NS	AS
Deep SSI	1	1
Organ space SSI	2	1
Anastomotic leak	1	1
<i>C. diff</i> colitis		1
Dehydration / acute kidney injury	4	2
Minor SBO / ileus	2	1
Major SBO requiring surgery		2
Seizures	1	
Thromboembolic events	3	
Pneumonia without respiratory distress	1	
Total	15	9

SSI surgical site infection, *C. diff* Clostridium difficile, UTI urinary tract infection

compared to the NS group (15/113, 13.3%; Table 2). We found through bivariate analyses that tobacco use (20.7% current users, $p=0.0475$) and procedure type (44.8% LAR, $p=0.004$) are imbalanced among readmitted patients. After adjusting for these imbalances, we found the odds of readmission for a patient in the ITT group to be 0.429 times the odds (95% CI: 0.184–1.002) of readmission in the NS group, although these odds were not statistically significant ($p=0.0504$). (Table 6).

As-treated analysis

Overall, we found the AS group had fewer patients (9/123, 7.3%) visiting the ED compared to the NS group (16/113, 14.2%). Upon completing bivariate analyses of ED visit patient demographics, we found that tobacco use (24% current users, $p=0.0257$) and procedure type (48% LAR, $p=0.0400$) are imbalanced among those visiting and not visiting the ED. After adjusting for tobacco use and procedure type in our model, we found that the AS group is statistically less likely to have an ED visit. Their odds of visiting the ED are 0.356 times the odds (95% CI: 0.138–0.919) of the NS group visiting the ED at a p value of 0.0328 (Table 6).

Similarly, the AS group also had fewer readmitted patients (8/123, 6.5%) prior to or on POD 30 when compared

to the NS group (15/113, 13.3%; Table 2). We found through bivariate analyses that sex (65% male, $p=0.0353$), tobacco use (26% current users, $p=0.0109$), and procedure type (68% LAR, $p=0.0798$) are imbalanced among readmitted patients. After adjusting for tobacco use, sex, and procedure type, we found that the AS group is statistically less likely to be readmitted. Their odds of readmission are 0.343 times the odds (95% CI: 0.132–0.892) of readmission for the NS group at a p value of 0.0283 (Table 6).

Use of APDS

Following analysis of APDS program data, 28 AS patients (28/123, 22.8%) used the mobile application to communicate significant clinical complaints and were managed without ED visits or readmission. Common themes of these patient issues that were managed via APDS included incisional pain, wound and drain discharge concerns, vomiting, abdominal pain, concerns of stoma prolapse, and wound infections (Fig. 3). One patient was recommended to visit the ED following complaints of difficulty breathing.

Discussion

Healthcare systems across the world are burdened with avoidable postoperative ED visits and consequent readmissions [1–5]. Current studies, as well as our own institutional data, show LOS is shortening as a result of ERAS programs; however, the benefits gained from a shorter LOS is potentially being offset by these avoidable ED visits and readmissions [2, 12–14]. Other studies have investigated the feasibility of APDS programs after surgery, but not in patients already on the ERAS protocol [6, 7, 9–11]. To date, our study is the first to find that integrating an APDS program into a healthcare institution's ERAS protocol results in a reduction of both ED visits and hospital readmissions. Our ITT model analyzed the entire patient population to which

APDS was offered. Patients in this group were not necessarily compliant in their use of the APDS application. The ITT model indicated lower odds of a patient in this cohort visiting the ED or being readmitted than the NS cohort, although these odds were not statistically significant. This indicates that resources should not only be allocated towards providing active surveillance to surgical patients; more importantly, resources should also be allocated to ensure that patients find it easy and convenient to engage and utilize the service. Our as-treated model excluded non-compliant patients and found the odds of an AS patient being readmitted or visiting the ED to be significantly lower than an NS patient. Such reductions in ED visits and readmissions will without a doubt result in higher patient satisfaction with quality of care and significant cost savings.

The adoption of ERAS programs is rapidly growing due to its proven attributes such as reduced LOS, postoperative complications, and costs [15–18]. Both groups in our study were on the ERAS protocol during their index surgery. However, we found the AS group stayed approximately 2 days less than the NS group. This finding can potentially have significant implications on maximizing a patient's gain from an even earlier discharge, distribution of healthcare resources, and cost savings. We believe the presence of APDS, allowed both surgeons and patients to feel more comfortable to accept earlier discharge.

The mean age of the AS patients in our study was 60 with a standard deviation of 13.8 years. Naturally, concerns arise with aging populations not being able or willing to participate in such a telemedicine platform. However, a survey study of the APDS platform Mobile Health Technologies (mHealth), assessed the willingness to engage in mHealth following surgery for a variety of socioeconomic factors [7]. The study reported no association between age and willingness to use the platform, although older populations were less likely to own a smartphone [7]. In our institution, patients were given the option of having their caregiver or family member utilize the APDS application for them to mitigate such issues of age when they arose. The availability of a desktop-compatible program, as well as an automated telephone service, further improved accessibility of the APDS to older adults. Furthermore, our platform allows liberal use of visual media to deliver patient complaints; we have noticed better patient satisfaction and compliance due to this, regardless of age.

The AS group had 12 total ED visits, one-third of which were avoidable. The most common chief complaints were postoperative fever and N&V. All were managed at the hospital using treatment plans that could have easily been conducted in an outpatient setting the next day or at home by a community nurse, patient caregiver, or the patients themselves. Given these considerations, we believe these visits were the result of improper use of the APDS

Table 6 Summary of statistical analyses of intent to treat and as-treated models

	Intent to treat model (ITT vs. NS)	As-treated model (AS vs. NS)
ED visits		
Odds ratio	0.493	0.356
95% CI	0.218–1.113	0.138–0.919
p value	0.0887	0.0328
Readmissions		
Odds ratio	0.429	0.343
95% CI	0.184–1.002	0.132–0.892
p value	0.0504	0.0283



Fig. 3 Conversation between surgeon and patient depicting a save where a wound infection was resolved via APDS

program by the patient. Some patients, despite being enrolled in the APDS program and engaging with the program initially, would at times stop responding to daily surveys and checkups, or would ignore inquiries regarding the necessity of a follow-up phone call. It is not clear if this was due to technical difficulty in using the application, or the patient being overwhelmed by the frequent reminders and checks. We believe future studies should look further into the difficulties patients face during the use of telemedicine technology, and what type of education and support patients need to better utilize these applications. Identifying solutions to these difficulties could potentially convert many avoidable visits and readmissions to *saves*. When we looked at our own data to see how 28 patients in the AS group avoided ED visits, we found these *saves* were typically the result of patients' liberal use of visual media to remotely show their care team what they considered to be the pertinent aspect of their complaint. It appeared that greater emphasis on the visual component of the APDS programs might be associated with more compliant, efficient, and frequent use of these programs.

The widespread availability of an effective APDS program has benefits beyond potential cost savings [7, 10]. If used appropriately, APDS can grant patients peace of mind, alleviating the anxiety and stress of waiting for the surgeon to answer back their calls—which can sometimes take hours, if not days. Moreover, patients do not need to worry about whether their hard-to-describe issue warrants a simple phone call to their surgeon or an ED visit. Rather, they can send a picture or a text message that can deliver their major concerns, which can potentially be managed at home or the next available outpatient appointment. Furthermore, APDS has an automated reminder and alert system embedded within the program. Failure for a patient to complete a simple questionnaire will push an alert to the patient's healthcare team. This allows for the physician's office to follow-up with a patient in situations that may have previously gone unnoticed until circumstances worsened to the point where a greater intervention becomes necessary.

APDS monitoring can also save the care team time. Although the actual amount of time saved was not recorded in this study, the colorectal surgeons reported APDS availability saved them time. APDS allows the surgeon to address patient concerns via quick text messages in the morning, evening, and between procedures. This amounts to short, scattered intervals of a few minutes each throughout the practitioner's daily workflow in lieu of the significant amount of time needed to return phone calls to patients. APDS cut out the time needed to look up a patient's phone number, waiting to reach the patient on the phone, working extensively with an answering service, and leaving voice messages. Furthermore, the surgeon could

easily add in a member of his office staff or home health RN to address questions of clerical nature. The office staff also noted a decrease in call volume with increased APDS adoption, specifically in regard to the after-hours answering service.

Study Limitations

The single institution, retrospective nature of this study presents inherent limitations. First, information biases may manifest as a result of misclassification or misinterpretation of patient records. So long as the researcher had not been involved with the patient directly, natural charting nuances over this patient population's timespan and size will introduce a certain degree of bias into the retrospectively collected data. Similarly, capturing all data points for all patients in the pool is not always feasible. Moreover, variance between chief complaints and charted diagnoses illustrates a discontinuity between patients and staff; multiple staff members in distinct units triage, treat, and chart on the patient. Unfortunately, this is simply the nature of emergency care. In an effort to mitigate this limitation, two board-certified colorectal surgeons independently reviewed each patient encounter involving an ED visit, readmission, or both to classify and understand each patient's complication; any disagreements were resolved by a third reviewer.

Future Work

Analysis of American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) readmission and ED visit data from the entire hospital is currently underway. Preliminary results are consistent with data yielded from our methods. Future studies should be prospective in nature and employ a dedicated research team. A multi-center study would also prove beneficial as it would increase sample size and test power. Further, beneficial insights could be made if the multi-center study involved regions of multiple socio-economic strata. Staff dedicated to instructing all patients on proper APDS program use and active data collection that are crucial to alleviate the inherent, prior-discussed limitations of retrospective chart review.

Conclusion

We believe APDS program integration into the ERAS protocol can help reduce ED visits and readmissions. Overall, we found significantly lower odds of a patient visiting the ED or being readmitted when using APDS, when patients engaged in and utilized the service.

APDS establishes both a cost-effective and convenient line of communication between patients and their surgical

team. Many ERAS patients are discharged early from the hospital at index surgery, gaining tremendous medical benefits from their early discharge as well as contributing to significant cost savings; however, with the use of APDS, they can be discharged even earlier, potentially yielding even more benefits. The APDS platform provides patients and healthcare providers with greater peace of mind, in addition to a swift, scalable, and secure communication platform. We believe supporting APDS adaptation by healthcare institutions will prove beneficial, not only with inherent cost-savings, but more importantly, better patient outcomes.

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Compliance with ethical standards

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