

ARTICLE



Bariatric Surgery

Feasibility and satisfaction with remote digital postoperative follow-up using a three-tiered alert system after bariatric surgery

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INTRODUCTION: With the global prevalence of obesity steadily increasing, bariatric surgery has gained significance in managing this health challenge. Fast-track healthcare pathways have shown promise in improving outcomes and patient satisfaction for bariatric surgery. In this study, we aimed to evaluate the safety and feasibility of responsive remote digital postoperative follow-up using a smartphone application.

MATERIALS AND METHODS: Consecutive patients undergoing bariatric surgery at CHU Saint-Pierre University Hospital between September 2022 and October 2023 were prospectively enrolled. Patients were instructed to download and install the application on their smartphones, which prompted them with predetermined daily questions. Depending on their responses, alerts could be generated for review by medical staff. A three-tiered alert system (orange, red, red+) was implemented to signify increasing significance. Comparisons between categorical variables were conducted using Fisher's exact test, while comparisons between continuous variables were assessed using the one-way Analysis of Variance (ANOVA) test for normally distributed data and the Mann-Whitney *U* test for non-normally distributed data.

RESULTS: During the study period, a total of 1119 alerts were recorded from 104 patients, with 39.3% occurring within the first seven postoperative days. Patient alert profiles were significantly associated with postoperative outcomes, with worsening outcomes observed from basic orange alerts to red+ alerts. Patients with red+ alerts had nearly a threefold increase in postoperative morbidity rates, emergency department visits, and readmissions. No significant differences in weight loss outcomes were observed. Patient response adherence was 67.5%, while the overall satisfaction with the use of the application was 94%.

CONCLUSION: Remote follow-up via a mobile application holds promise for enhancing the management of bariatric surgery patients, complementing traditional practices. The implementation of a three-tiered alert system may help identify patients at risk of serious complications, potentially reducing unnecessary emergency department and hospital resource utilization.

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INTRODUCTION

Obesity surgery has gained increasing relevance in addressing associated morbidity, with sleeve gastrectomy and Roux-en-Y gastric bypass (RYGB) emerging as primary interventions [1]. This trend can be attributed in part to the standardization and improved safety of such procedures in recent years. The adoption of minimally invasive surgery techniques and enhanced recovery protocols has played a pivotal role in this regard, facilitating faster patient recovery and shorter hospital stays without compromising outcomes [2]. Consequently, this shift not only underscores the growing favorability of bariatric surgery but also highlights its potential cost-effectiveness,

particularly considering the substantial socio-economic impact of obesity-related morbidity on affected populations.

With the role of obesity surgery firmly established, ongoing efforts are directed toward optimizing patient outcomes. Despite the already short postoperative hospitalization period, typically averaging one to two days in most cases [3], attention must now shift to the immediate post-discharge phase for two primary reasons: firstly, to ensure successful and sustained weight loss within an acceptable timeframe, and secondly, to facilitate smooth patient recovery. It is noteworthy that a significant proportion of complications arise in the days following hospital discharge [4], underscoring the imperative need for postoperative patient surveillance.

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In this regard, the widespread adoption of modern technologies, particularly mobile smartphones, holds promise for substantial benefits by facilitating remote patient follow-up without the need for cumbersome office or hospital visits. This approach not only minimizes the time spent in healthcare facilities but also ensures timely and accurate addressing of patient concerns, thereby potentially enhancing the appeal of such interventions to the general public. While evidence on this topic remains limited, a previous meta-analysis comparing remote digital surveillance with conventional follow-up has shown equivalence in terms of safety and weight loss outcomes, suggesting the feasibility of such a strategy [5].

In this context, the use of mobile applications for remote patient monitoring represents a promising avenue for enhancing postoperative care, particularly for bariatric surgery patients. The primary objective of this study was to assess the utility of a mobile application with a three-tiered alert system in identifying bariatric surgery patients who may be at higher risk for postoperative complications. Specifically, we aimed to evaluate whether alert profiles generated by the app correlate with the occurrence of complications, the need for intensive follow-up care, and healthcare resource utilization, such as emergency department visits and rehospitalizations. While the app does not predict complications directly, we hypothesize that it can help clinicians identify patients who could benefit from closer monitoring and timely intervention. This approach aims to enhance postoperative care by providing proactive support, potentially improving outcomes and reducing unnecessary healthcare resource usage.

MATERIALS AND METHODS

Consecutive patients undergoing bariatric surgery at the CHU Saint-Pierre University Hospital between September 2022 and October 2023 were prospectively enrolled in this study, which involved remote perioperative follow-up via a mobile application. Ethical approval was obtained from the medical ethics committee of CHU Saint-Pierre (Protocol number: B0762022220903). The study was conducted in accordance with the STROBE guidelines [6].

Digital follow-up by mobile application

The “Care4Today monitoring” mobile application, developed by Q1.6, was selected in the current study for the digital follow-up of patients. This application engages patients in active monitoring during the crucial 60-day period following their discharge, addressing various aspects such as nutrition, wound care, pain management, and patient well-being. The objective of this mobile application is to serve as a communication tool between Health Care Professionals (HCPs) and patients, facilitating post-discharge patient surveillance. The software comprises a patient interface and an HCP portal. The patient interface is a smartphone application available for Android and iOS devices, which prompts patients with a set of daily predefined questions. Based on the patients’ responses, alerts are generated and transmitted via daily emails, direct email, or directly to the healthcare provider dashboard. This system enables informed decision-making and proactive intervention as necessary. All data stored within the Q1.6 application adhere to GDPR compliance standards, employing multi-layered encryption and anonymized formats wherever feasible.

Questionnaire and alert framework

The questionnaire framework is structured in a smart decisional algorithmic tree format, with questions tailored to various aspects of postoperative care based on their timing (Supplementary Fig. 1). Depending on the patients’ responses, a color-coded alert (orange, red, or red+) may be generated, reflecting the severity and projected clinical impact of the response. Orange alerts prompt an automatic email sent to the medical staff in the morning for review. Red alerts trigger an immediate email to be sent and reviewed by the medical staff, while red+ alerts prompt the patient to immediately contact the medical staff or present to the Emergency Department for further evaluation (Table 1). The questionnaire framework and notification decision tree were meticulously crafted by a team of experienced surgeons specializing in obesity surgery, in collaboration with Ethicon (Johnson & Johnson Medical Technologies).

This collaborative effort ensures that the application addresses pertinent concerns and provides tailored support to patients.

Digital coordinator

All patients were encouraged to download and install the application on their devices with the support of a digital coordinator who served as a liaison between patients and medical staff. This initiative aimed to reduce the digital divide and enhance access to postoperative remote follow-up. The digital coordinator’s role included ensuring that each patient understood and effectively utilized the application, as well as promptly communicating any alerts to the medical staff.

Patient eligibility criteria

All adult patients scheduled for primary obesity surgical intervention or conversion surgery from one type of intervention to another were considered potentially eligible for the study. Informed consent was obtained through the application, and patients were explicitly given the opportunity to opt out of the study at any time. Given the observational nature of the study, no prospective sample size calculation was applicable. Patients were excluded from the study if they were underage (<18 years old), unwilling to participate, lacked a mobile phone capable of installing the application, were unable to use it due to language constraints, or initially agreed to participate but failed to provide any answers via the application.

Details of patient management and surgical interventions

All bariatric interventions were performed by the same team of five surgeons specializing in obesity surgery. Bariatric surgery options included sleeve gastrectomy, RYGB, single anastomosis stomach-ileal bypass with sleeve gastrectomy (SASI-S), or conversion to a RYGB following a previous bariatric intervention. Patients were considered for bariatric surgery if their BMI was greater than 40 or greater than 35 with associated obesity-related comorbidities, following established conventions. A multidisciplinary committee comprising members of the surgical team, a psychologist, and a nutritionist engaged with patients to determine the most appropriate surgical approach. In cases of revisionary bariatric surgery, the decision for conversion was based on patients’ symptoms, complaints and overall weight loss status. The study did not alter the standard of practice or routine patient follow-up. Discharge criteria remained unchanged, and no additional drugs, placebos, or non-food substances were administered as part of the study. Staff members were trained to verbally inform patients about the study’s purpose, and data generated by the application were managed in a time-sensitive manner.

Data handling, outcomes of interest, and definitions

Study site personnel utilized an electronic database capture system to transfer data from source records (including medical records and source document worksheets). Q1.6 managed the data according to the data processing agreement. The primary data of interest included the number and type of alerts registered, as well as the timing of alerts during the 60-day postoperative follow-up period. Early alerts occurred within 7 days of the surgery, while late alerts were those communicated thereafter. Additionally, patient baseline demographics and procedure-related outcomes, such as complication rates and severity classified by the Clavien-Dindo scale, were collected. Data on postoperative visits to the emergency department (ED), hospital readmissions, and reinterventions within the 60-day postoperative timeframe were also gathered. These data were supplemented with information on postoperative weight loss at 1-month, 3-month, and 6-month milestones. A longer follow-up period for weight loss outcomes was considered more appropriate to provide a comprehensive assessment. Secondary data of interest encompassed patient compliance and mobile application utilization rates, as well as satisfaction with the application’s usability. To ensure uniformity in data presentation, the following definitions regarding postoperative weight loss were applied:

% Total weight loss (% TWL): $(\text{preoperative weight} - \text{current weight}) / \text{preoperative weight} \times 100$

% Excess weight loss (% EWL): $(\text{preoperative weight} - \text{current weight}) / (\text{preoperative weight} - \text{ideal weight}) \times 100$

The ideal BMI was estimated at 25 kg/m², with the ideal body weight calculated directly from it, factoring in patients’ heights.

Table 1. List of alerts and notifications generated by the application depending on patients' answers.

Type of alert	Phase	Notification	Action
Orange	Preoperative	- Patient would like information to help stop smoking	An e-mail with all orange alerts of the last 24 h will be sent to the medical staff at the morning
		- Patient feels quite bad the day before surgery	
	Postoperative	- Patient does not understand discharge info	
		- Patient has moderate pain and is taking painkillers (VAS between 6 and 7)	
		- Patient has one of the following conditions: "worsening cough", "chest pain", "shortness of breath", "swollen/painful leg", "dizziness", "temperature >38.5 °C"	
		- Patient experiences problem with wound	
		- Patient's wound is not dressed and not kept clean	
		- Patient doesn't understand the recovery exercises	
		- Patient's activity level is half than it was before surgery and is in pain	
		- Patient is not feeling well	
	Late postoperative (31 days postoperatively)	- Patient has abdominal pain or tenderness in the shoulders	
		- Patient has pain when eating	
		- Patient is experiencing one or more of the following symptoms: "heartburn", "nausea/vomiting, abdominal pain", "difficulty eating/swallowing", "dumping syndrome symptoms", "other (non-specified) complaints"	
		- Patient has lost more than 10% weight	
	General questions (asked at prespecified time points)	- Patient is not able to follow guidelines around time to eat a meal	
		- Patient is experiencing one or more of the following symptoms: diabetes, high blood pressure, fast heart rate, breathing problems, heart problems, kidney failure, sleep apnea, joint condition(s), high cholesterol, other (non-specified)	
		- Patient has pain when eating	
		- Patient suffers from a decrease in quality of life	
Red	Preoperative	- Patient feels terrible the day before surgery	An instant e-mail will be immediately sent to the medical staff
	Postoperative	- Patient has a lot of pain and is taking painkillers (VAS between 8 and 9)	
		- Patient has wound separation or gaping wound	
	Late postoperative (31 days postoperatively)	- Patient didn't drink today	
		- Patient has been vomiting for 3 days	
Red+	Postoperative	- Patient has two or more of the following conditions: "chest pain", "shortness of breath", "swollen/painful leg"	The patient will be presented with a notification to immediately contact the medical staff or present to the Emergency Department
		- Patient has severe pain and is taking painkillers (VAS of 10)	

VAS Visual Analog Scale of pain.

Patient compliance and satisfaction

Patient compliance with the use of the mobile application was assessed at the 60-day postoperative milestone. The number of responses for each previous day was calculated during this period, resulting in an overall response rate.

Patient satisfaction was evaluated using the mHealth App Usability Questionnaire (MAUQ), specifically designed for stand-alone applications [7]. This tool comprises 18 items categorized into three main components: ease of use (5 items), interface and satisfaction (7 items), and overall usefulness (6 items). Each item was scored from 0 to 5, with 0 indicating

complete disagreement with the statement and 5 indicating complete agreement. An overall satisfaction score between 0 and 90 was generated for each patient who responded to the questionnaire. These scores were then converted to a scale from 0 to 10 to facilitate data presentation.

Statistical analysis

Descriptive statistics were employed to present the collected data. Categorical variables were expressed as absolute numbers with corresponding percentages, while continuous variables were represented as means with standard deviations for those exhibiting a normal distribution and as medians with ranges for those displaying non-normal distributions. The normality of the data was assessed using the Kolmogorov-Smirnov test. Comparisons between categorical variables were conducted using Fisher's exact test, while comparisons between two groups of continuous variables were assessed using the one-way Analysis of Variance (ANOVA) test for normally distributed data and the Mann-Whitney *U* test for non-normally distributed data. Additionally, the Kruskal-Wallis non-parametric test was employed for comparing multiple groups of non-normally distributed variables. A significance level of $p < 0.05$ was applied to determine statistical significance and two-tailed tests were used where applicable.

RESULTS

A total of 136 patients undergoing bariatric surgery from September 2022 to October 2023 were initially considered for inclusion in the study. After the exclusion of 32 patients (Fig. 1), 104 patients who utilized the "Care4Today monitoring" application were ultimately included. No patients were lost during the follow-up period. Among these participants, 85 (81.7%) were female and 19 (18.3%) were male, with an average age of 35.6 ± 12 years (range: 18–66 years). The median patient BMI at the time of operation was 41.5 (range: 21.4–64.8), with patients at the lower end of the spectrum receiving secondary conversion bariatric surgery. Specifically, 10 patients (9.6% of the sample) underwent revisionary surgery with conversion to RYGB, while the majority underwent primary obesity procedures, primarily RYGB ($n = 67$, 64.4%), sleeve gastrectomy ($n = 20$, 19.2%), or single anastomosis stomach-ileal bypass with sleeve gastrectomy (SASI-S) ($n = 7$, 7.6%). Overall, 101 patients (97.1%) exhibited at least one obesity-related comorbidity, with sleep apnea and arterial hypertension being the most predominant ($n = 41$, 39.4% and $n = 24$, 23.1%, respectively). A total of 1119 alerts from 101 patients, were registered during the 61-day period, starting from the day before surgery (postoperative day -1) up to the 60th day postoperative milestone (Supplemental Fig. 2). Among these alerts, orange alerts were the most frequent ($n = 1027$, 91.8%), followed by red alerts ($n = 74$, 6.6%) and red+ alerts ($n = 18$, 1.6%). The median number

of orange alerts per patient was 10, while three patients did not register any alerts despite using the application.

Postoperative complications were observed in 24 patients (23%), with only 4 (16.7%) classified as potentially serious (Clavien-Dindo grade $> II$). No patient deaths occurred during the study period. There were a total of 17 visits to the emergency department by 12 patients (11.5%), resulting in 10 readmissions for 8 patients (7.7%), of which three underwent a reintervention in the form of exploratory laparoscopy. Table 2 provides a high-level overview of patient baseline data.

Postoperative weight loss

The analysis of weight loss by alert profile is exploratory in nature and weight loss data are reported primarily for context. Most patients experienced steady weight loss from baseline during the 6-month postoperative follow-up period (refer to Table 3). The median weight loss at the 6-month milestone was 27 kg (range: 7.2–58.9 kg), corresponding to a reduction in median BMI from

Table 2. Baseline patient parameters and characteristics.

		Number of patients <i>n</i> (%)
Sex	Male	19 (18.3)
	Female	85 (81.7)
Age (years) ^a		35.6 ± 12
Preoperative BMI		41.5 (21.4–64.8)
Comorbidities	Smoking	15 (14.4)
	Alcohol consumption	6 (5.8)
	Hypertension	24 (23.1)
	Sleep apnea	41 (39.4)
	Diabetes	18 (17.3)
	GERD	17 (16.3)
Previous abdominal surgery		36 (34.6)
Previous bariatric surgery		10 (9.6)
Postoperative Morbidity	Total	24 (23)
	$\leq$ Clavien-Dindo grade II	20 (83.3)
	$>$ Clavien-Dindo grade II	4 (16.7)
Types of Surgery	Sleeve gastrectomy	20 (19.2)
	Roux-en-Y gastric bypass	67 (64.4)
	SASI-S	7 (6.7)
	Conversion to bypass	10 (9.7)
Length of Hospital stay (days)		2 (1–7)
Number of alerts	Orange	1027 (91.8)
	Red	74 (6.6)
	Red+	18 (1.6)
	Total	1119
Emergency department visits		12 (11.5)
Readmissions		8 (7.7)

^aValues presented as mean and standard deviation.

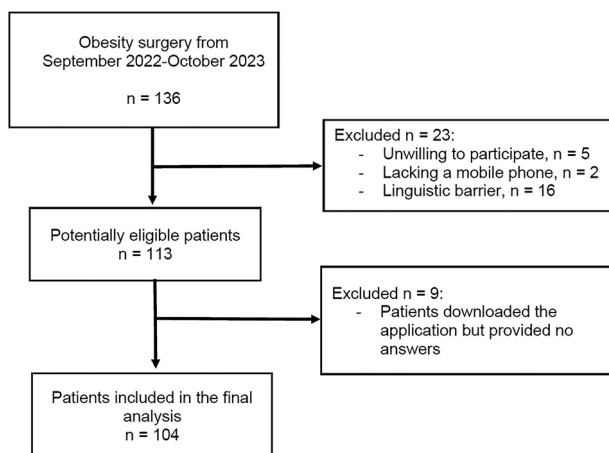


Fig. 1 Patient selection flowchart.

Table 3. Follow-up data on weight loss.

	1 month	3 months	6 months
Postoperative BMI	37.8 (28.7–59.5)	33.5 (24.7–51.3)	31.2 (22.5–46.1)
Total weight loss (kg)	10.6 (–1.4–25.5)	22.7 (1.2–35.3)	27 (7.2–58.9)
%TWL	9.2% (–1.2–17%)	18.4% (1.2–35.3%)	22.8% (7.5–39.8%)
%EWL	22.8% (–2.6–53.4%)	46.2% (8.6–102.6%)	57.9% (26.8–124.5%)

TWL% total weight loss (percentage), EWL% excess weight loss (percentage).

Data are presented as median (range).

Table 4. Outcomes of patients depending on the type of alert profile.

Type of alert	Orange alerts <10	Orange alerts ≥10	Red alerts	Red+ alerts	p-value
Number of patients	53	21	22	8	
Total number of alerts	194	324	318	280	
Age ^a	36.6 ± 11.6	39.5 ± 12.6	31.7 ± 11.8	32.3 ± 10.4	0.08
ED visits, <i>n</i> (%)	3 (5.7)	0	5 (22.7)	4 (50)	0.002
Readmission, <i>n</i> (%)	2 (3.8)	0	3 (13.6)	3 (37.5)	0.008
Morbidity	3 (5.7)	5 (23.8)	10 (45.5)	6 (75)	<0.001
%TWL at 6 months	23.1% (15.5–38.9%)	21.9% (13.4–35.5%)	22.7% (13–39.8%)	25.2% (13–39.8%)	0.25
%EWL at 6 months	57.9 (30.8–82.3)	56.7 (26.8–124.5)	53.9 (31.8–91)	55.2 (32.1–81.5)	0.31

^aValues presented as means with standard deviation.

41.5 at baseline to 31.2 (range: 22.5–46.1). At the end of the follow-up, the median %TWL was 22.8% (range: 7.5–39.8%), with an associated median %EWL of 57.9% (range: 26.8–124.5%), indicating effective weight control through the interventions employed. Notably, there was a single patient who initially experienced a 1.4 kg weight gain 1 month following sleeve gastrectomy, which subsequently reverted to a 14.5 kg weight loss by the end of follow-up.

The impact of alerts on postoperative patient management

Nausea/vomiting and abdominal pain were identified as the primary triggers for both orange and red alerts (Supplementary Fig. 3). Orange alerts, by definition, were associated with symptoms of lower severity compared to red alerts, while red+ alerts always indicated symptoms suggestive of a potentially significant postoperative complication requiring immediate medical attention. Consequently, patients were categorized into four subgroups based on their alert profiles to facilitate comparisons of postoperative outcomes. The first subgroup comprised patients with fewer than 10 orange alerts and no red or red+ alerts, while the second subgroup consisted of patients with more than ten orange alerts but no red or red+ alerts. The third subgroup included patients with a red alert (irrespective of whether they also had orange alerts), and the fourth subgroup encompassed patients with red+ alerts (Table 4).

While the mean age did not exhibit significant differences between the compared subgroups, a trend toward higher mean age was noticeable in the subgroups with orange-only alerts. Emergency department (ED) visits and hospital readmissions were significantly higher in the red and red+ subgroups ($p = 0.002$ and $p = 0.008$, respectively) compared to the other subgroups. Interestingly, among the eight patients with red+ alerts, only four ED visits were recorded that led to three rehospitalizations. %TWL and %EWL at 30 days postoperatively were comparable across the subgroups. Morbidity rates were significantly higher in the red and red+ subgroups, reflecting a higher incidence of postoperative complications (45.5% and 75%, respectively) compared to the orange alert subgroup ($p < 0.001$).

Table 5. Alert profile and patient outcomes in the first postoperative week as opposed to the later postoperative period.

	Early postoperative period (≤7 days)	Late postoperative period (>7 days)	p-value
Total alerts	439	680	<0.001
Orange alerts	380 (86.5)	646 (95)	
Red alerts	45 (10.3)	30 (4.4)	
Red+ alerts	14 (3.2)	4 (0.6)	
ED visits, <i>n</i> (%)	2 (1.9)	10 (9.6)	0.03
Readmission, <i>n</i> (%)	1 (0.9)	7 (6.7)	0.07

Alerts during the early and late postoperative periods

Of the total number of alerts, 439 (39.2% of the entire pool) were recorded within the first postoperative week (early postoperative alerts), while the remaining 680 (60.8%) were registered in the 53-day period that followed (late postoperative alerts). Although orange alerts were predominant in both time periods, the early postoperative period saw an almost double prevalence of red alerts. Table 5 provides a detailed breakdown of alert types based on their timing of presentation. Notably, only two patients (1.9%) visited the Emergency Department during the early postoperative period, with one patient (0.9%) being readmitted during the early postoperative period. Most ED visits occurred during the late postoperative period, involving ten patients (9.6% of the entire cohort), of whom seven (6.9%) were rehospitalized.

Patient compliance and satisfaction

Out of a total of 19,325 questions sent out during the 60-day postoperative period, 13,049 responses were received, resulting in an overall response rate of 67.5%. The highest adherence rates were observed during the first postoperative week, ranging from 75% to 92%, and gradually declining thereafter (daily response

rates for the first 30 postoperative days are available for review in Supplemental Fig. 4).

In total, 75 patients responded to the satisfaction questionnaires. All these patients successfully adhered to the 60-day postoperative monitoring period using the application. The overall median satisfaction score was 9.3 out of 10 (ranging from 7.8 to 10). Concerning the subcomponents of the MAUQ questionnaire, the median patient satisfaction with the ease of use was 10 out of 10 (range: 6–10). Satisfaction rates were also comparable regarding the interface usability (median score of 9.8, range: 8.2–10), while patient perception of the overall usefulness of the application was slightly lower (median score of 8, range: 5.7–8.6).

DISCUSSION

In the present study, we aimed to outline our experience with digital follow-up for patients undergoing bariatric surgery and assess its integration within a streamlined postoperative healthcare pathway designed to minimize healthcare resource utilization while maintaining patient safety and satisfaction. To achieve this goal, we propose a mobile application solution featuring a three-tiered alert system. This system serves a dual purpose: firstly, to provide patients with guidance on addressing any healthcare concerns that may arise during the postoperative period, and secondly, to provide healthcare personnel involved in their management with timely updates on the patient's status. The rationale behind this approach is clear: remote follow-up via a digital mobile application aims to shorten hospitalization duration, reduce unnecessary utilization of emergency services, thereby lowering the rate of hospital readmissions, and enhance satisfaction among all stakeholders by offering an easy-to-use platform that complements existing standards of care.

Bariatric surgery is well-suited for remote follow-up, given its short hospitalization period and prolonged postoperative monitoring phase. Mangieri et al. [8] conducted the first assessment of a commercially available mobile application as a postoperative adjunct in a randomized controlled trial (RCT) with 56 patients. They found that application users experienced significant weight reduction over a 24-month follow-up period compared to non-users, suggesting potential postoperative outcome enhancement. However, the selected mobile application lacked specific adjustments for bariatric surgery and thus did not include postoperative patient surveillance. In a subsequent study, Heuser et al. [9] observed comparable length of hospital stay, ED visitation rates, and readmission rates between patients using a mobile application for follow-up and those who did not. Similarly, Yang et al. [10] investigated replacing standard office-based follow-up with digital application follow-up, concluding that remote follow-up is as effective as traditional practice. While these studies demonstrate the feasibility of remote follow-up via mobile applications, none of them effectively enabled responsive remote patient status monitoring.

One of the key findings of our study was the association between patients' alert profiles and not only emergency department presentations and rehospitalizations but also the presence of postoperative complications. Patients with red and red+ alerts exhibited a two to three times higher incidence of postoperative complications compared to those with orange or no alerts ($p < 0.001$). This concordance between the patients identified as experiencing elevated risk by the mobile application and documentation of complications and emergency care in the medical record constitutes preliminary evidence that the application is useful for identifying patients who could benefit from additional care. This feature has the potential to be pivotal in shifting the current practice paradigm from a reactive stance to a more proactive one. Furthermore, despite nausea, vomiting, and abdominal pain being the predominant triggers for alerts in the majority of patients, the application's scope was expanded to

encompass a broader range of topics that may affect patient well-being during the postoperative period, thus allowing for a more accurate portrayal of current patient status.

It's worth noting that more than a third of the total number of alerts occurred during the first 7 postoperative days, coinciding with the period when bariatric patients typically experience transitory symptoms and are most susceptible to postoperative leaks [11]. During this early phase, patients exhibited nearly double the rates of red and red+ alerts compared to the later postoperative period, although most emergency department visits and rehospitalizations occurred afterward. This finding aligns with similar observations in other studies [12], given the longer duration of the latter period. However, considering the relatively low number of emergency department visits and readmissions despite the high number of red and red+ alerts ($n = 59$) during the early postoperative phase, remote follow-up via a mobile application may serve as an effective triage and counseling system during these critical initial days, acting complementarily to known risk factors [13].

In terms of postoperative weight outcomes, the cohort did demonstrate satisfactory progression during the 6-month follow-up period, though subgroup analysis did not reveal any significant association between patient alert profile and TWL or EWL outcomes. This analysis is exploratory, and while we hypothesize that patients with more severe symptoms (e.g., red and red+ alerts) might experience poorer weight loss due to potential challenges in adhering to postoperative guidelines (such as dietary recommendations or activity levels), further investigation is needed to explore this potential relationship. This lack of significance might stem from the short postoperative follow-up available; however, observed reductions in weight are consistent with reports from other studies focusing on the same time span [14]. Another plausible explanation is that mobile applications structured in a questionnaire format may not effectively promote increased activity and thus potentiate weight loss. This could also explain the controversies in currently existing studies comparing remote follow-up via digital application platforms to standard practice. Specifically, weight loss outcomes are equivalent in two studies using a questionnaire-based system [10, 14], while the single RCT on the topic [9] indicates that significant weight loss can be expected with the integration of interactive applications oriented towards dietary and activity surveillance.

Patient adherence to postoperative follow-up is a crucial aspect of bariatric surgery care. Numerous risk factors for non-adherence have been identified [15], and evidence suggests that adequate adherence is essential for achieving initial weight loss [16]. In our study, the overall adherence rate was 67.5%, with adherence peaking during the early postoperative period and gradually declining thereafter. This adherence rate is comparable to rates associated with conventional follow-up [17], indicating successful compliance with the mobile application's use. Patient satisfaction, as measured by the Mobile Application Usability Questionnaire (MAUQ), was also high, with a median score of 9.3 out of ten, indicating satisfaction with its ease of use.

This study has several limitations. Firstly, it is a single-center observational study, which, despite being conducted prospectively, is susceptible to selection bias. Although efforts were made to include patients from diverse socioeconomic backgrounds and a digital coordinator was employed to enhance patient inclusivity, some patients were excluded due to language barriers or lack of access to a mobile phone. Secondly, the follow-up period of 6 months may have been too short to adequately assess differences in outcomes such as weight loss. Additionally, comparative analyses may have been affected by confounding bias, as adjustments for confounding factors were not feasible with the available dataset. Furthermore, it is worth noting that in the present study, adherence to other postoperative measures, such as vitamin supplementation or lifestyle changes was not

monitored. Finally, although satisfaction was overall high, only 72% of patients replied to the relevant questionnaire.

In conclusion, this study underscores the potential of remote patient follow-up using a questionnaire-based mobile application with a three-tiered alert system in the postoperative care of bariatric surgery patients, enabling responsive remote monitoring. The significant association between patient alert profile and emergency department visits, hospital readmissions, and post-operative morbidity indicates the application's ability to identify at-risk patients and potentially reduce unnecessary healthcare resource utilization. High adherence rates and patient satisfaction further support the feasibility and acceptance of the mobile application. Overall, remote follow-up via mobile application offers a promising approach to enhancing the management of bariatric surgery patients, providing a proactive supplement to traditional practices.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

Conceptualization (EF, GB), Methodology (DP, NK), Software (MT), Validation (MP), Formal analysis (DP, AR), Investigation (NK, AR), Resources (EF), Data Curation (NK, AR), Writing—Original Draft (DP, EF), Writing—Review & Editing (AP), Visualization (DP, NK), Supervision (EF, GB).

COMPETING INTERESTS

The authors declare no competing interests.

PATIENT CONSENT

Written informed consent was obtained from all included patients. Written informed consent was obtained from all participants in the current study.

ADDITIONAL INFORMATION

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