Original Research Article

Development and Validation of a Mobile Application for Predicting the Risk of Anastomotic Leakage in Patients Operated for the Treatment of Colorectal Cancer

ABSTRACT

Background: the scientific literature presents some tools for predicting the risk of anastomotic leakage in patients operated on for the treatment of colorectal cancer. However, a mobile application for this purpose has not been built yet. **Aim**: to build and validate a mobile application capable of predicting the risk of anastomotic leakage in patients operated for the treatment of colorectal cancer. **Methods**: an application containing a prognostic index for urgent colectomy and an index for elective colectomy was built (Leak Index). This application was validated by judges in the area of general surgery and coloproctology using the SUS table (Scale Usability System). **Results**: regarding the general evaluation, it is observed that the judges agree regarding the usability of the application, with a general S-CVI of 0.90 being registered, above the criterion of 0.80, which corresponds to 90.01% of general agreement of the evaluators. Raters mostly agree on ease of use (I-CVI = 0.95) and that people will quickly learn to use it (I-CVI = 0.955). **Conclusion**: an application with excellent usability rates was built to predict the risk of anastomotic leakage in patients who underwent colectomy for the treatment of colorectal cancer.

Keywords: Colorectal neoplasms. Anastomotic Leakage. Risk factors. Prognostic Index

1. INTRODUCTION

Colorectal cancer (CRC) is one of the most common types of cancer in adults and one of the most lethal: approximately 9.4% of cancer-related deaths were due to CRC in 2020 [1].

For non-metastatic resectable colon cancer, the surgical procedure of choice is colectomy with removal of lymph nodes en bloc [2]. One of the most feared complications of colectomy is anastomotic leakage (AL), affecting postoperative recovery as well as cancer progression [3].

Strategies to anticipate and/or control the risk of AL have been pointed out in the world literature as a possibility of reducing complications, contributing to better postoperative prognosis. From this perspective, some authors developed tools capable of predicting the risk of AL in patients operated on for the treatment of CRC. Dekker and partners [4], for example, using some risk factors, developed a scale capable of predicting the risk of AL. Rojas-Machado and collaborators [5], in turn, developed a software containing a prognostic index, called PROCOLE, with the same objective. In addition to these, Frasson and partners

[6] developed an online calculator, with variables that stratify the risk of AL in patients undergoing colectomy.

Although these studies represent advances in the ability to predict AL, these tools have limitations, especially with regard to their difficult application and usability in medical practice. They are tools little used in medical practice, or even unknown by professionals in the area. Thus, more efforts are needed in an attempt to develop tools to predict the risk of AL that are effective, of good applicability and compatible with the practical demands of surgeons.

The popularization of mobile devices has been considered the technological revolution with the greatest impact in recent years, and the development of computational solutions in the form of applications for mobile devices represents an effective means of making content available and reaching a certain audience.

An excellent way to try to reduce the risks of AL is the development of a mobile application containing indices capable of accurately predicting the probability of developing AL in patients operated on for the treatment of CRC, with the construction and validation of this tool being the main objective of this study.

2. MATERIALS AND METHODS

2.1. Ethical aspects

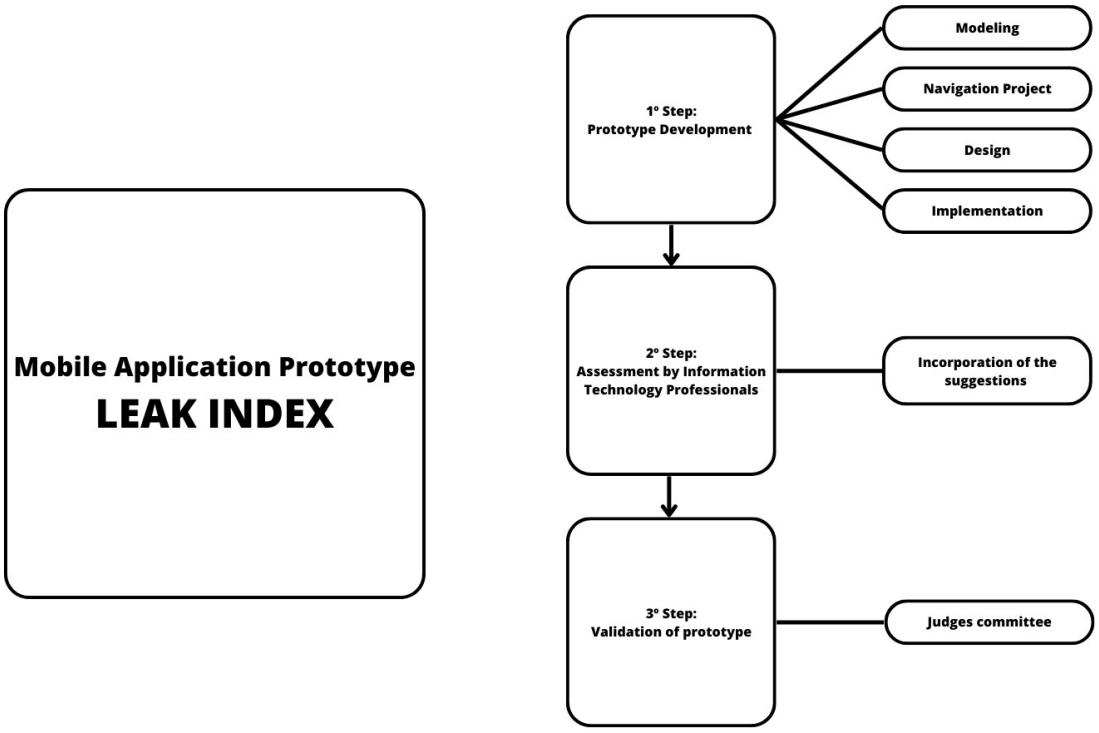
This study followed the ethical and legal precepts of research involving human beings, according to Resolution 466/12 of the National Health Council. It was approved by the Research Ethics Committee of Santa Casa de Belo Horizonte (CAAE: 36476320.2.0000.5138) and the participants were informed about the objectives of the study, the voluntariness of their participation and asked to sign the Term of Free and Informed Consent (TFIC).

2.2. Study design, period and place

This is a methodological study, centered on the construction and validation of a cell phone application containing prognostic indices capable of predicting the risk of AL in patients operated on for the treatment of CRC. The study was carried out from March to December 2022 at Faculdade Santa Casa BH, in Belo Horizonte (Minas Gerais) and at Hospital São José do Avaí, a large philanthropic hospital located in Itaperuna (Rio de Janeiro).

The study was developed according to the steps described in figure 1.

Figure 1 – Flowchart of the study steps. Belo Horizonte, Minas Gerais, Brazil, 2022.



Source: Research data, 2022.

Participants, inclusion and exclusion criteria

The validation of the application was carried out through its evaluation by a committee of judges, composed of professionals in the field of general surgery and coloproctology. The composition of the committee of evaluators followed the guidelines of Alexandre and Coluci [7], which indicate the participation of at least three individuals from each group of professionals.

Specialists in the area of general surgery and coloproctology were considered, surgeons with residency in general surgery and/or coloproctology, with experience in colectomies. Surgeons with less than 50 cases of videolaparoscopic colectomy were excluded from the study, for not having enough experience [8], as well as those who operate less than 2 videolaparoscopic colectomy weekly. The medical area judges selected were those belonging to the General Surgery and Coloproctology Service of the Hospital São José do Avaí, Itaperuna (Rio de Janeiro), as well as other professionals in the area, who met the above criteria, indicated by these same judges.

Prior to the invitation to participate in the study, the lattes curriculum of the judges were evaluated. To participate in the research, it was necessary for the surgeon to score at least 5 points in the thematic areas: academic work at the master's and doctoral level (1 point for each); author of at least one published article (1 point per article); participation in groups and/or surveys (1 point per participation); participation in evaluation boards at undergraduate and postgraduate lato sensu and stricto sensu levels (1 point for each participation); teach discipline (1 point per year); professional care experience in CRC treatment (0.5 point per year); guide work at undergraduate and graduate levels lato sensu and stricto sensu (0.5 per work) [9].

The contact with the judges was made via email or messaging application (WhatstApp), with the sending of an invitation letter to participate in the application validation process. This one dealt with aspects of the study, such as objectives and information about the research. Those who agreed to participate in the survey received another email or message to fill in the TFIC, the SUS and demographic assessment questionnaires [10] and the link containing the App in the web and Android versions.

A period of 15 days was granted to complete and send the evaluation instruments, and this period was extended for another 15 days, with a new contact being made with further clarifications, and, when there was no response, within the established period, the judge was excluded.

2.3. Study Protocol

Step 1: Prototype development

The elaboration of the hypermedia system presented four steps: modeling, navigation design, abstract interface design and implementation [11].

In the modeling stage, the content of the application was defined and the way in which it should be presented to the target audience. The contents are two indices for the prognosis of AL in patients operated on for the treatment of CRC: preoperative index derived from the meta-analysis [12] and the urgency index performed from a historical cohort [12, 13]. The preoperative index contains 13 variables, while the urgency index has four, all of which are risk factors for the occurrence of AL. Both were developed and validated by this research group with the specific purpose of predicting the risk of AL in patients operated on for CRC treatment and composing the content of this application [12, 13]. Below is the weight of each factor obtained through meta-analysis and the equations for obtaining the indices. The value of the preoperative index comes from the “Weight”, adding the positives.

Table 1 – Weight of each preoperative index factor

Risk Factors	Weight (b)
Gender (male)	0,351
Tabagism	0,392
Neoadjuvant chemotherapy	0,770
Neoadjuvant radiotherapy	0,859
Previous Abdominal Surgery	0,262
Diabetes mellitus	0,678
Pulmonary Disease	0,761
ASA III and IV	0,531
CPOD	0,095
Coronary disease	0,476
Chronic kidney failure	0,300
Urgency surgery	0,476
Alcoholism	0,300

The probability equation:

$$Prob(Leak = Positive) = exp(\alpha) / (1 + exp(\alpha)); where:$$
$$\alpha = -3{,}450 + 1{,}025 \times Pre - operative\ index$$

The probability cutoff is 0.12, or 12%.
The index cutoff point is 1.421.

Urgency index:

$Prob(Leak = Positive) = exp(\alpha) / (1 + exp(\alpha))$; where:

$$\begin{aligned}\alpha = {} & -2{,}222 - 1{,}586 \times I(Age = From\ 36\ to\ 45\ years\ old) \\ & -1{,}100 \times I(Age = From\ 46\ to\ 55\ years\ old) \\ & -1{,}401 \times I(Age = From\ 56\ to\ 65\ years\ old) \\ & -2{,}881 \times I(Age = Above\ 65\ years\ old) \\ & + 2{,}415 \times I(Chemotherapy = Positive)) \\ & +1{,}872 \times I(Previous\ surgery = Positive) \\ & +2{,}244 \times I(Urgency\ surgery = Positive)\end{aligned}$$

The result is a probability. The cut-off point is 0.054, that is, 5.4%. Below that, a low AL index. Above this value, a high AL index.

In the navigation project, the menus that make up the application were defined, with their respective texts, images, tables and the way they are organized within the application. The platforms were PHP, HTML and JAVASCRIPT and for the database, the Firebird 3.0.7 (2020 – program language SQL) was used and the development of images was made with the Corel Draw.

In the abstract interface project, it was defined the appearance of the system and the specification of which interface objects the user will be able to view [14].

Then, there was the elaboration of prototypes to establish the best way of presenting information to the surgeon from the application. After the previous steps and detailed review, the project was implemented for the Android platforms and the Web version.

Step 2: Assessment of Information Technology Professionals

At the end of the prototype development stage, a meeting was held with the professionals from the Santa Casa BH Innovation Discussion Group, who are part of the Santa Casa BH Innovation Committee, with the presentation of the application. This group is made up of Information Technology professionals. Professionals evaluated the application and made suggestions that were implemented, with the aim of making the application simpler and more dynamic, facilitating its use by surgeons.

After being evaluated by IT specialists and making the adjustments they suggested, the prototype was submitted to the validation stage by professionals in the field of surgery and coloproctology.

Step 3: Application Validation

For validation of the prototype by medical professionals, the System Usability Scale (SUS) questionnaire was used, as adapted by Padrine-Andrade and collaborators [10]. SUS is a simple, ten-item scale that provides an overview of subjective usability assessments [15]. The questions pertaining to the SUS were graded on a Likert-type scale, with values from

one to five, classified respectively as: “strongly disagree”, “disagree”, “neither agree nor disagree”, “agree” and “strongly agree”. Only the last question was a non-compulsory essay.

After data collection, the final score was calculated, which generated a unique number. To calculate the score, first the value of each item that contributes on a scale from 1 to 5 is added. For items 1, 3, 5, 7 and 9, the individual score is the grade received minus 1. For items 2, 4, 6, 8 and 10, the contribution is 5 minus the grade received. The sum of all scores is multiplied by 2.5 and thus the total value of the SUS is obtained [15]. After scoring and calculating the score, it is possible to classify the evaluated system: 13 to 20.5 (worst imaginable); 21 to 38.5 (poor); 39 to 52.5 (median); 53 to 73.5 (good); 74 to 85.5 (excellent); and 86 to 100 (best imaginable).

The demographic questionnaire, in turn, contained the following characteristics: gender (male and female), age, maximum level of education (medical residency, master's, doctorate), professional area (general surgery or coloproctology) [10]. For surgeons: how many colectomies for the treatment of CRC they had already performed after the end of medical residency and the average number of colectomies they performed weekly.

2.4. Statistical analysis

Analyzes of the demographic questionnaire and SUS were carried out. Categorical variables were described by absolute and relative frequencies. The variables calculated regarding age were: average, standard deviation, median, minimum and maximum.

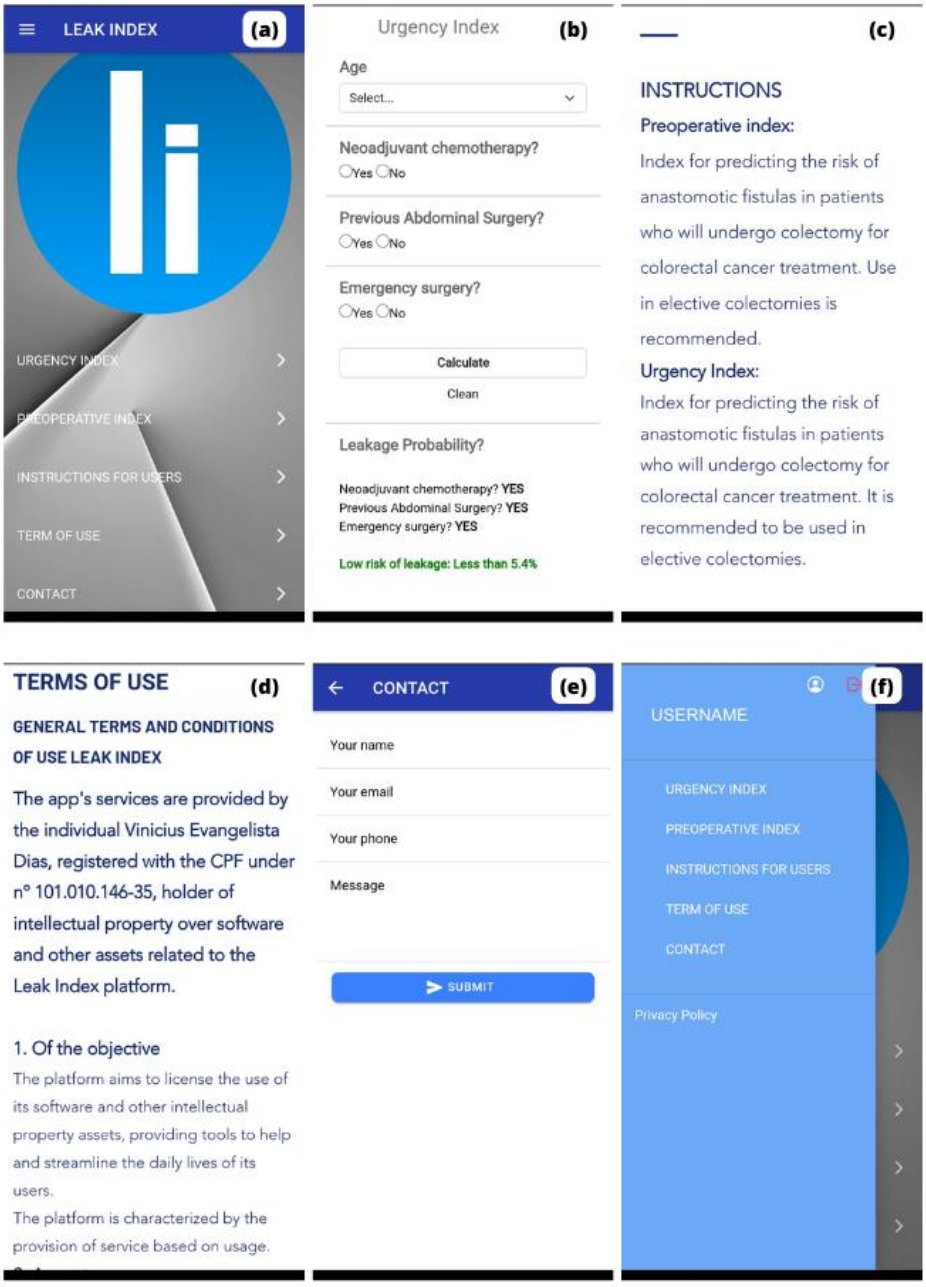
For the SUS questionnaire, the content validity indexes I-CVI (item-level content validity index) and S-CVI/Ave (scale-level content validity index based on the average method) were calculated, with the objective of knowing the app usability.

IBM SPSS version 25, Microsoft Excel and R-STUDIO (version 4.1.0) software were used to carry out the analyses.

3. RESULTS

Phase 1 resulted in the development of an application prototype named “Leak Index”, found in the web [16] and android [17] versions. After downloading to the mobile device, the “Leak Index” prototype can be found on the main screen of the devices. Methodologically, the prototype was built from an initial presentation screen, a primary screen containing the icons for accessing the urgency index, the preoperative index and an icon for accessing user instructions; in addition to a secondary screen containing icons to access the terms of use and contact with developers.

Figure 2 – Mobile application prototype. Belo Horizonte, Minas Gerais, Brazil, 2021.



(a) Home Menu; (b) Urgency Index; (c) Instructions for users; (d) Terms of use; (e) Contact; (f) Sidebar Menu;

Professionals from the information technology area of the Santa Casa BH Innovation Committee suggested changes to the User Interface to improve the User Experience, with modifications to the icons, their layouts and colors to facilitate understanding. Also, changes were made to the flowchart.

The application validation stage was carried out by 22 judges from the field of general surgery and coloproctology, who reached the minimum score for participation in the study,

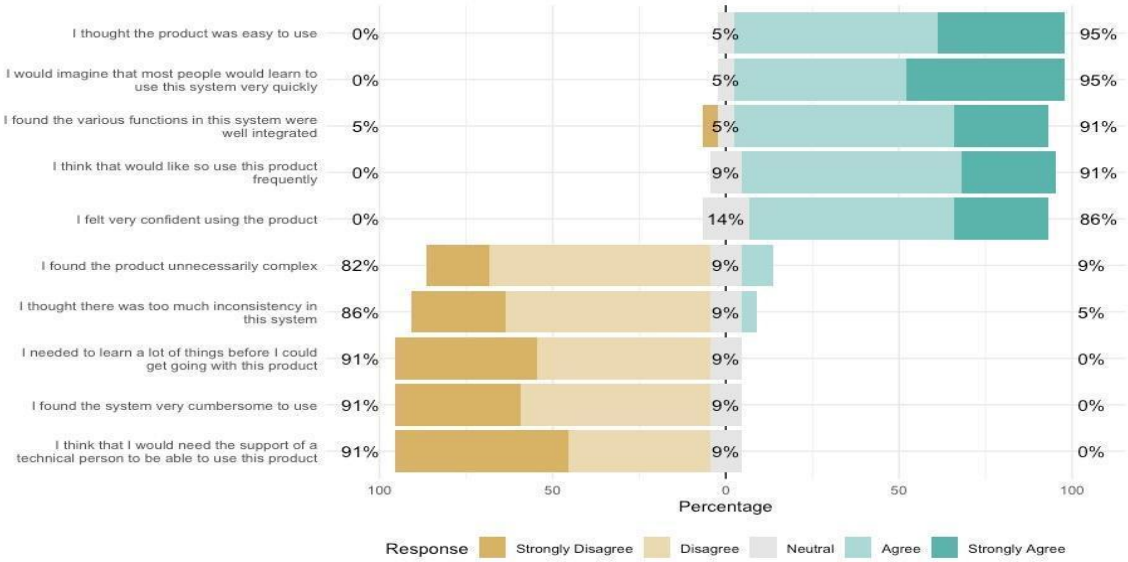
through the analysis of the lattes curriculum and the minimum number of required colectomies. Most men (59.09%) with a mean age of 37.3 years (±8.9).

Table 2 – System user characteristics (n = 22)

Gender	
Feminine	9 (40,91%)
Masculine	13 (59,09%)
Level of education	
Doctorate degree	1 (4,55%)
Master's degree	7 (31,82%)
Medical Residency	14 (63,64%)
Medical Residency	
General Surgery	19 (86,36%)
Coloproctology	3 (13,64%)
Age (years)	
Average (standard deviation)	37,3 (8,9)
Median (min - max)	34,5 (28 - 66)

It is observed that, in general, the evaluators agree that the application is easy to use (95%) and that other people would quickly learn about the usability of the application (95%). About 91% of raters agree that the app has well-integrated functionality and 5% of raters disagree. A total of 91% of the evaluators agree that it is not necessary to have instructions for using the application, as well as not considering it difficult to use. It is noteworthy that the item with the lowest percentage of agreement was in relation to the evaluators' confidence to use the application (86%), where about 14% of the evaluators were neutral on this item.

Figure 3 – Quantitative of evaluators' responses



With regard to the general evaluation, it is observed that the evaluators agree regarding the usability of the application, with a general S-CVI of 0.90 being registered, above the criterion of 0.80, which corresponds to 90.01% of general agreement of the evaluators. Raters mostly agree on ease of use (I-CVI = 0.95) and that people will quickly learn to use it (I-CVI = 0.955). About 86.4% of evaluators disagree that the application has many inconsistencies (I-CVI = 0.86) (Table 3).

Table 3 – Metrics for usability validation and agreement of the instrument

Item	Experts in Agreement	I-CVI	% Agreement	IC 95%
I think that I would like to use this product frequently	20	0,91	90,90%	0,552 - 1,00
I found the product unnecessarily complex	18	0,82	81,80%	0,494 - 1,00
I thought the product was easy to use	21	0,95	95,50%	0,574 - 1,00
I think that I would need the support of a technical person to be able to use this product	20	0,91	90,90%	0,527 - 1,00
I found the various functions in this system were well integrated	20	0,91	90,90%	0,552 - 1,00
I thought there was too much inconsistency in this system (disagree)	19	0,86	86,40%	0,508 - 1,00
I would imagine that most people would learn to use this system very quickly	21	0,95	95,50%	0,565 - 1,00
I found the system very difficult to be used	20	0,91	90,90%	0,532 - 1,00
I felt very confident using the product	19	0,86	86,40%	0,508 - 1,00
I needed to learn a lot of things before I could get going with this product	20	0,91	90,90%	0,527 - 1,00
S-CVI/Ave		0,90	90,01%	

At the end of the instrument, the evaluators were offered the opportunity to spontaneously leave considerations, suggestions or criticisms. Of the total of 22 evaluators, 9 indicated some point of improvement, including the suggestion of including nutritional status (albumin), as well as stratifying the risks better. Other reviewers rave about the app. And one reviewer suggested improvement in product design.

4. DISCUSSION

The SUS questionnaire demonstrated excellent usability rates for the “Leak Index” application. Both the questions analyzed separately and the general evaluation achieved satisfactory results, proving the usability of this system.

Despite all the advances in medicine, AL is still the most feared surgical complication in colorectal surgery [6], which suggests the great interest of surgeons in an application capable of predicting its occurrence.

The application is divided into two indexes, previously validated [13], one recommended for urgency because it has fewer variables (four), and another for elective surgeries, with 13 variables. The two scales are easier to use than the scale constructed by Rojas-Machado et al. [5], which has many variables (23), some of which are difficult to obtain, requiring prior examinations. One of the variables, for example, divides surgeries into ultra-low, low and intraperitoneal anterior resections, which makes it even more difficult for physicians to use it, since often, only intraoperatively will the height of the anastomosis be known.

Another factor that contributed to the outstanding result is the fact that it is an application. As previously mentioned, other efforts were made to build instruments capable of predicting the risk of AL, however, all of them with low usability. Dekker et al. [4] built a score, without any support for its application, making it difficult to use the tool. Rojas-Machado and colleagues [5], in turn, developed software for use on a computer, which also makes its use in hospital routine unfeasible. Frasson et al. [6], on the other hand, built a website containing an online calculator that has few variables, however, it requires unfeasible information to create an index, such as serum protein dosage that requires tests and intraoperative complications that prevent the determination of risk prior to surgery. In addition, it is easier and more practical to use a specific application than a website. All these previous efforts are less usable, which justifies the non-adherence of surgeons to the use of these AL prediction instruments.

Cell phones are part of people's daily lives and for many it is considered an extremely important tool, as a single device is capable of centralizing functions such as internet access, work, leisure, studies, health care, among others [18]. This fact also helps to explain the great importance of an application for predicting the risk of AL in patients operated on for the treatment of colorectal cancer, as mobile devices are more integrated into a physician's daily life.

The questions with the lowest scores were “I felt very confident using this product” and “I found the product to be more complex than necessary”. Despite these questions having reached an adequate score, it is believed that the greater use of the application by the surgeon, for a longer time in their clinical practice, as well as the knowledge of this article, in addition to the translation into the native language, could improve even more these questions.

The use of this application by surgeons can help reduce the risk of AL in patients who will be operated on for the treatment of colorectal cancer, because before the procedure, the

surgeon will be able to identify patients with a greater chance of fistula and then promote actions that aim to reduce the factors modifiable risk. In addition, as there are no intra or postoperative variables, the physician can start the procedure, knowing the risk of AL and taking all measures during and after surgery, to reduce the chance of this complication, maintaining greater vigilance regarding patients with the worst rating.

Through the use of the application, the surgeon will be able to inform the patient about the need for a protective ostomy in advance, if the patient is classified as high risk, talking to the patient and requesting the consent form for surgical treatment.

A limitation of the application is that it only provides a qualitative probability, not providing the corresponding numerical value. Furthermore, the device is found only in English and still does not have an iOs version to the present date, although the authors have already answered all the questions raised by the platform. IPhone users, however, can use the web version.

Prospective studies with the use of the application by surgeons, with a larger number of patients, are necessary for a better evaluation and possible improvements for this tool.

5. CONCLUSION

An application for mobile devices, called Leak Index, was created, containing two prognostic indices for predicting the risk of AL in patients operated on for the treatment of CRC. This index has a recommended index for urgency colectomies and an index for elective colectomies. This application was validated using the SUS table by judges in the field of general surgery and coloproctology, achieving excellent usability rates. More studies are suggested for better understanding and future improvements of this tool.

CONSENT

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL

This study was approved by the Research Ethics Committee of Santa Casa from Belo Horizonte. CAAE: 36476320.2.0000.5138.

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