Evaluation of the efficacy of wireless sterilizable pulse oximeter in assessment of bowel viability during surgery

Haitham S.E. Omar[a], Ahmed F.A. Farag[a], Vijay P. Sah[a], Ahmed A. Mohsen[b], Abdrabou N. Mashhour[a]

[a]Department of General Surgery, Kasr Al Ainy Hospitals, Faculty of Medicine, Cairo University, Cairo, Egypt, [b]Department of General Surgery, National Research Centre, Cairo, Egypt

Correspondence to Haitham S.E. Omar, MD, Department of General Surgery, Faculty of Medicine, Cairo University, Manial Elrawda, Cairo, 11562, Egypt. Tel: +201006575370; e-mail: haitham_omar1@yahoo.com

Received: 10 April 2020
Accepted: 3 June 2020
Published: 29 September 2020

The Egyptian Journal of Surgery 2020, 39:879–888

Background
Intestinal viability is crucial before commencement of any anastomoses or establishment of stomas after resection of the gut for any surgical reason, and depending on the clinical sense and subjective methods alone may result in disastrous results and complications affecting the outcomes of the surgical procedures. There are many techniques available nowadays for assessing bowel viability, but most of them are technically demanding and not usually available in the operating theater, besides the cost of many of them, which may represent another added burden. For all the aforementioned reasons, the wireless pulse oximeter (PO) has emerged as a possible new method which can aid in assessment of bowel viability during surgeries with the advantages of availability, low cost, and simple rapid way of gut viability assessment.
Purpose
The aim of this study was to evaluate the capability of the wireless PO in discrimination between viable and nonviable intestine intraoperatively before establishment of stomas or intestinal anastomoses.
Study design
This was a prospective study that included 40 patients who were evaluated intraoperatively by the wireless PO to assess the viability of the proximal and distal ends of the intestine. The intestinal viability in the first 10 patients was also evaluated by the fluorescein dye in addition to the PO. Here, fluorescein was used as a well-established method to validate the new technique of the PO.
All the readings were recorded, and patients were followed up for 2 weeks postoperatively to detect any complications related to intestinal ischemia.
Results
Three cases were complicated: two cases of failed anastomosis with leakage and the third case was ischemic end colostomy stoma. The mean values of PO readings in the noncomplicated group (37 cases) were 95.65 and 96.32% in the proximal and distal segments, respectively, whereas in the complicated group (three cases), mean values were 89 and 87% in the proximal and distal segments, respectively.
Conclusion
The PO device is safe, portable, and nonsophisticated, which can be used easily by surgeons in assessment of bowel viability during surgery. It takes less time to assess the intestinal viability and is very cost-effective, as one device can be used in multiple patients.

Keywords:
fluorescein, intestinal anastomoses, pulse oximeter

Egyptian J Surgery 39:879–888
© 2020 The Egyptian Journal of Surgery
1110-1121

Introduction

Mortality related to intestinal ischemia remains very high. Patient survival depends on prompt recognition in dealing with the ischemic part either by revascularization or excision. Furthermore, if intestinal ends that are not perfectly vascularized are anastomosed, this anastomosis is bound to fail resulting in peritonitis. Thus, exact determination of the borderline of the viable bowel with the help of an objective test could result in a decrease of postoperative ischemic complications.

During operation, distinction of viable from nonviable intestine is not always easy. Frequently, a bowel loop that looks healthy and is left in the abdomen will develop gangrene within 1 or 2 days, hence the policies of a second-look surgery. Waiting for fixed color changes to develop may take a long time, and actually, very precious time is wasted.

For this, Horgan and Gorey [1] stressed on the need of a reliable intraoperative viability test. They advised five

criteria for an ideal one, which are as follows: (a) the technique must have ready availability, preferably in every operating theater dealing with abdominal emergencies; (b) the necessary equipment must not be cumbersome or require specialized personnel; (c) the method must be accurate with a minimum of false-negative results, and more importantly, few false-positive results (a false-negative result leaves in situ nonviable bowel, whereas a false-positive assessment of bowel viability results in the resection of potentially recoverable intestine, which is lost forever); (d) the technique must be objective and be reproducible; and (e) the method must be cost-effective.

Aim

The aim of the present study was to assess the capability of the portable wireless sterilizable pulse oximeter (PO) in detection and discrimination between viable and nonviable intestine intraoperatively before establishment of stomas or intestinal anastomosis.

Patients and methods

Patients

The present study included 40 patients who came to the outpatient department and emergency department of Kasr Al Ainy Hospital, from March 2018 to September 2018, in whom there was a possibility of acute intestinal ischemia. Patients with intestinal ends that were intended for anastomosis after resection of eitherbenign or malignant diseases; and those with ends intended to be brought out as a stomas (jejunostomy, ileostomy, or colostomy) were also included in the study.

After agreement from the Scientific and Ethical Committee of General Surgery Department and Faculty of Medicine, Cairo University, the procedure and the study were explained to all individuals participating in the study, and informed written consents were taken.

All patients were evaluated by PO to assess the viability of the proximal and the distal ends of the intestine. From the 40 patients, the first 10 were also evaluated by the fluorescein dye, to assess the intestinal viability [2–4]. Here, fluorescein is used as a well-established method to validate the new technique of PO.

Inclusion criteria

Patients of either sex and of any age in whom possibility of acute intestinal ischemia was present were included, for example:

(1) Strangulated hernia.
(2) Acute mesenteric vascular occlusion.
(3) Intussusception.
(4) Volvulus.
(5) Suspected injury of mesenteric vessels during dissection or after penetrating injuries.
(6) The ends of intestinal loops that are intended for anastomosis after resection for either benign or malignant diseases.
(7) The end of a bowel segment that is intended to be brought out as a stoma (jejunostomy, ileostomy, or colostomy).

Exclusion criteria

Patients with advanced cardiopulmonary diseases or on inotropes for circulatory support were excluded.

Methods

Full history of patients (including age, sex, medical and surgical history, comorbidities) was taken from all patients. Full laboratory and radiological assessment was done and in some patients, colonoscopy±biopsy was also done to prove tumor.

All patients were placed under general anesthesia for operation, either open or laparoscopic. Overall, one ampoule of 5 ml of 10% of fluorescein sodium IP (a well-known and established method in diagnosis of

Figure 1

Fluorescein sodium IP.

intestinal viability) was pushed I/V in the peripheral veins (Fig. 1). The I/V doses of fluorescein sodium used for colorectal surgeries are in the range of 0.5–10 ml of 10% fluorescein in the USA and 0.5–10 ml of 1% fluorescein in various centers around the world.

A hand-held device that emits ultraviolet rays to detect fluorescein at 350–365 nm is used as a light source (Fig. 2). To visualize the dye with ultraviolet light, complete darkness was instituted in the operation room (Fig. 3).

Pulse oximeter

Portable wireless sterilizable PO (Granzia AS-304; Shenzhen Acurio Instruments Co. Ltd, Italy) (Fig. 4) was used to assess the viability of the intestine by measuring the SpO_2 of that part. PO was sterilized by the plasma sterilization each time before being used.

Photography

Photographs were taken by a mobile camera (12 mp, f/2.2, 29 mm) and laparoscopic camera to record the intensity of fluorescence from tissues. The fluorescence images were taken in near absence of visible light. PO SpO_2 reading images were also taken by the same camera.

For the first 10 patients, fluorescein dye was injected intravenously before resection of the suspected ischemic part and after resection of the tumor and fistulous part of intestine to see its viability. After detecting the viable bowel by the fluorescein, the PO was placed on the antimesenteric border, as shown in Fig. 5a, b and 6a, b to see the SpO_2 of the viable intestine. These readings obtained by the PO were considered as the cutoff values at which the PO can distinguish between viable and ischemic intestinal segments during surgery because up till now there is no consensus on these values.

In the other 30 patients, intestinal viability was evaluated only by the PO by the same technique as explained before.

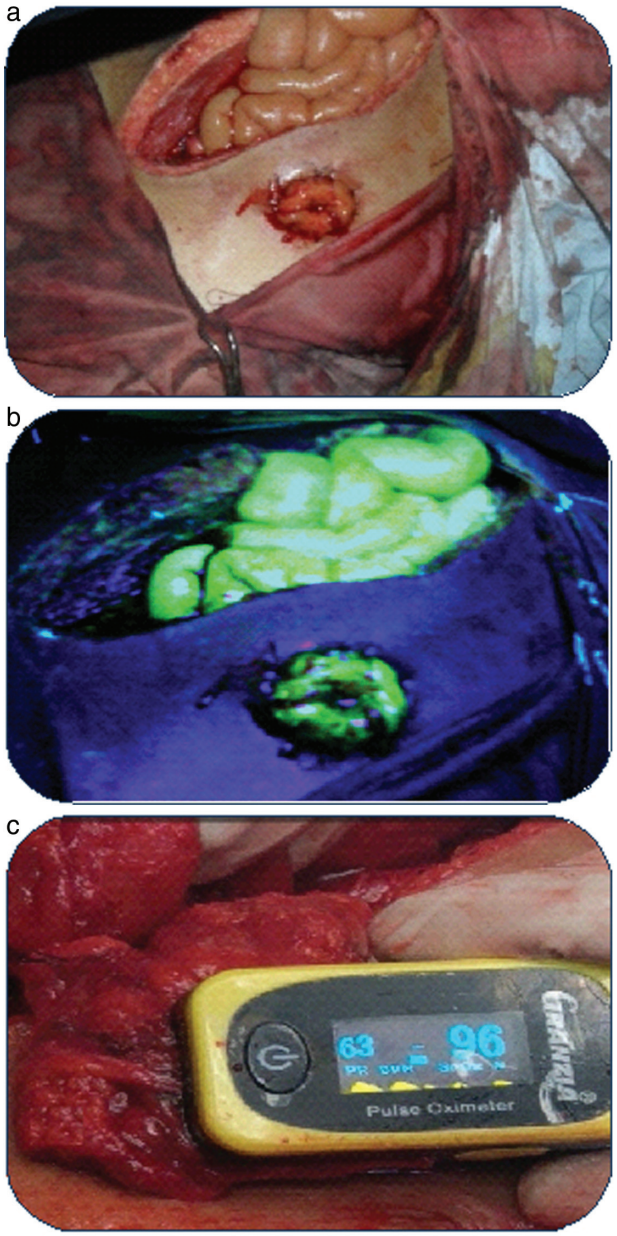
Intraoperative techniques for intestinal anastomosis

The resected segments were anastomosed in an end-to-end fashion, single layer (hand sewn) with Vicryl 3-0 absorbable sutures in the open cases. Colostomy and ileostomy were also fixed with the Vicryl 3-0 absorbable sutures, whereas in the laparoscopic and rectal carcinoma cases, a circular stapler was used.

Figure 2

Laser lightening system.

Figure 3



Sigmoid colostomy showing (a) normal colostomy (b) fluorescein fluorescence of colostomy (c) pulse oximeter showing SpO_2 readings of the resected segment before colostomy creation.

(1) Photographs were taken under all conditions for later evaluations.
(2) The final decisions, to either resect or to leave the part of intestinal segments and to anastomose the intestinal segments, were taken by senior operating surgeons without interference from the investigator.

Figure 4

Used pulse oximeter in our cases.

Postoperative

Data were collected in the form of excel sheet for later statistical analysis. The collected data are as follows:

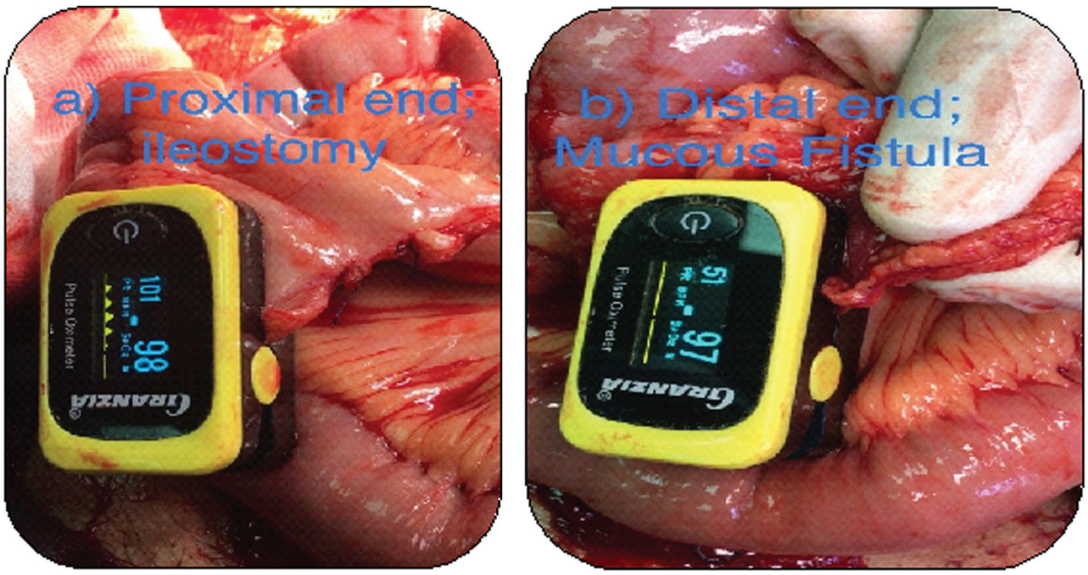
(1) Age.
(2) Sex.
(3) Diagnosis at presentation.
(4) Operation type.
(5) Operation technique.
(6) Operation procedure.
(7) Fluorescein fluorescence results.
(8) Proximal segments SpO_2 readings of PO.
(9) Distal segments SpO_2 readings of PO.
(10) Methods of anastomosis.
(11) Complications.
(12) Management.

Patient was followed up for 2 weeks to detect any complication related to intestinal ischemia.

Statistical analysis

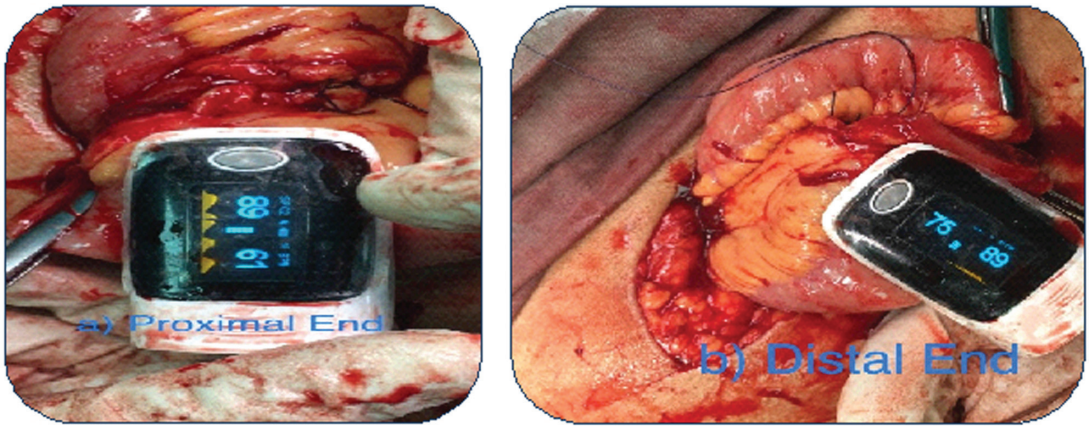
Data were statistically described in terms of mean±SD, median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Mann–Whitney *U* test for independent samples. For comparing categorical data, χ^2 test was performed. Exact test was used instead when the expected frequency is less than 5. *P* values less than 0.05 was considered statistically significant. Accuracy was represented using the terms sensitivity, specificity,

Figure 5



Intraoperative (right hemicolectomy for perforated colon) use of pulse oximeter on the antimesenteric border. (a) Proximal end ileostomy. (b) Distal end mucous fistula (noncomplicated case).

Figure 6



(a) Proximal end, (b) distal end showing pulse oximeter readings in bowel loop ends before anastomosis and after resection of strangulated bowel (complicated case after anastomosis).

positive predictive value, negative predictive value, and overall accuracy.

Accuracy calculations

Sensitivity = T(+)ve÷[T(+)ve + F(−)ve].

Specificity = T(−)ve÷[T(−)ve + F(+)ve].

Positive predictive value = T(+)ve÷[T(+)ve + F(+)ve].

Negative predictive value = T(−)ve÷[T(−)ve + F(−)ve].

Overall accuracy = [T(+)ve + T(−)ve]÷All sample.

All statistical calculations were done using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp., Armonk, New York, USA) release 22 for Microsoft Windows.

Results

Demographic and descriptive data

Total number of patients were 40.

The study included 21 (52.5%) males and 19 (47.5%) females.

Mean age±SD was 47.73±16.265; the minimum age was 17 years and the maximum age was 72 years.

Clinical diagnosis

The study included patients presented with the following diagnosis as shown in Table 1.

A total of 31 (77.50%) cases were operated upon through laparotomy, eight (20%) cases were done by a laparoscope, and one (2.5%) case was converted from laparoscopy to open.

Overall, 29 (72.5%) patients went through resection and anastomosis, five (12.5%) patients went through resection and colostomy, and two (5%) patients went through resection and ileostomy. No resection was done in four (10%) patients.

First 10 cases corelation between fluorescein fluorescence and SpO_2 of pulse oximeter

In eight cases in which fluorescein fluorescence was detected, PO also showed higher readings and there were no complications. Again, in the other two cases who experienced complications later on, there was neither fluorescein fluorescence detection nor PO signals (both PO signals were absent in the proximal segments) (Table 2).

Analysis of fluorescein fluorescence data

Of the 10 patients who were evaluated by fluorescein dye (green fluorescence by the lightening system), fluorescence was detected in eight (80%) patients and not detected in the other two (20%) patients in whom also complications had occurred afterward.

The fluorescein fluorescence data is of statistical significance, that is, *P* value of 0.022, as shown in Table 3.

Analysis of pulse oximeter data

SpO_2 readings in the pulse oximeter

In the proximal end, signals were detected in 38 cases, whereas in the remaining two cases, signals were absent. The minimum and maximum readings of the signals detected were 83 and 99%, respectively, with the mean value of 95.47% and with SD of ±3.236.

Concerning the distal end, signals were detected in 36 cases, whereas in the remaining four cases, it was not accessible owing to two cases of laparoscopic surgery (the distal ends cannot be brought outside) and one open case

Table 1 Clinical diagnosis of the cases included in the present study

	n	%
Colostomy or ileostomy closure	11	27.5
Intestinal obstruction	8	20.0
Rectal cancer	8	20.0
Colon cancer	2	5.0
Rectovaginal fistula	2	5.0
Acute abdomen	2	5.0
Sigmoid diverticulitis	1	2.5
Familial adenomatous polyposis	1	2.5
Ileum injury during hysterectomy	1	2.5
Sigmoid volvulus	1	2.5
Stab in right iliac fossa with prolapsed small intestine	1	2.5
Strangulated inguinal hernia	1	2.5
Strangulated umbilical hernia	1	2.5
Total	40	100.0

Table 2 Correlation between fluorescein fluorescence and SpO_2 of pulse oximeter in the first 10 patients

Serial numbers	Fluorescein fluorescence	SpO_2 of proximal segment (%)	SpO_2 of distal segment (%)	Complication
1	Not detected	Not detected	No distal segment	Yes
2	Detected	92	Can't access (laparoscopic)	No
3	Detected	96	95	No
4	Detected	96	Can't access (narrow pelvis)	No
5	Detected	97	97	No
6	Detected	98	95	No
7	Detected	93	98	No
8	Detected	98	96	No
9	Not detected in proximal end but detected in distal end	Not detected	99	Yes
10	Detected	99	99	No

Table 3 χ^2 tests (complications in relation to fluorescein fluorescence)

	Value	DF	Asymptomatic significance (2-sided)	*P* value	Exact significance (1-sided)
Pearson c^2	10.000 (b)	1	0.002		0.022
Continuity correction (a)	4.727	1	0.030		
Likelihood ratio	10.008	1	0.002		
Fisher's exact test				0.022	
Linear-by-linear association	9.000	1	0.003		

a. Computed only for a 2x2 table. b. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .40.

Table 4 SpO_2 in pulse oximeter

	Number	Minimum	Maximum	Mean±SD
SpO_2 of proximal	38	83	99	95.47±3.236
SpO_2 of distal	36	75	99	95.81±4.027

Table 5 Complications in relation to proximal segment signals

	Complication		
	No	Yes	Total
Pulse oximeter signals in proximal ends			
Not detected			
Count	0	2	2
% within oximeter signal proximal	0.0	100.0	100.0
% within complication	0.0	66.7	5.0
Detected			
Count	37	1	38
% within oximeter signal proximal	97.4	2.6	100.0
% within complication	100.0	33.3	95.0
Total			
Count	37	3	40
% within oximeter signal proximal	92.5	7.5	100.0
% within complication	100.0	100.0	100.0

of narrow pelvic region. In the fourth case, there was no distal end because APR with establishment of perineal colostomy was done. Minimum and maximum signals detected were 75 and 99%, respectively, with the mean value of 95.81% and with SD of ±4.027 (Table 4).

Complications in relation to proximal segment pulse oximeter signals

PO signals in the proximal end of the bowel were detected in 38 (95%) patients, whereas in the remaining two (5%) patients, the signals were not detected. Complication occurred in only one patient among the 38 cases in which signal was detected (this was mostly owing to low reading of SpO_2 of PO in the distal end, which was 75%); on the contrary, complications occurred in the other two patients in whom the signals were not detected (Table 5).

The detection of signals in the proximal end in relation to the occurrence of complication data is of statistical significance, that is, *P* value of 0.004 (Table 6).

Complications in relation to distal segment pulse oximeter signals

PO signals in the distal end of the bowel were detected in 36 (90%) patients. Among these 36 patients, two had complications (first one because of low SpO_2, i.e. 75%) and the other because signal was not detected in the proximal end). The other four patients in which signals

Table 6 χ^2 tests (complications in relation to proximal segment signals)

	Value	DF	Asymptomatic significance (2-sided)	*P* value	Exact significance (1-sided)
Pearson c^2	25.965(b)	1	0.000		0.004
Continuity correction (a)	13.826	1	0.000		
Likelihood ratio	12.062	1	0.001		
Fisher's exact test				0.004	
Linear-by-linear association	25.316	1	0.000		
Number of valid cases	40				

a. Computed only for a 2x2 table. b. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .15.

Table 7 Complications in relation to distal segment signals

	Complication		
	No	Yes	Total
Pulse oximeter signal in distal ends			
Not detected			
Count	3	0	3
% within oximeter signal distal	100.0	0.0	100.0
% within complication	8.1	0.0	7.7
Detected			
Count	34	2	36
% within oximeter signal distal	94.4	5.6	100.0
% within complication	91.9	100.0	92.3
Total			
Count	37	2	39
% within oximeter signal distal	94.9	5.1	100.0
% within complication	100.0	100.0	100.0

Table 8 χ^2 tests (complications in relation to distal segment signals)

	Value	DF	Asymptomatic significance (2-sided)	*P* value	Exact significance (1-sided)
Pearson χ^2	0.176(b)	1	0.675		0.850
Continuity correction (a)	0.000	1	1.000		
Likelihood ratio	0.329	1	0.566		
Fisher's exact test				1.000	
Linear-by-linear association	0.171	1	0.679		
Number of valid cases	39				

a. Computed only for a 2x2 table. b. 3 cells (75.0%) have expected count less than 5. The minimum expected count is .15.

were not detected were two laparoscopic, one narrow pelvis, and one case had no distal end as mentioned before 'perineal colostomy' (Table 7).

The detection of signals in the distal end in relation to the occurrence of complication data is not of statistical significance, that is, *P* value of 1.000 (Table 8).

Complications in relation to both proximal and distal pulse oximeter readings

The mean values of PO reading signals in the noncomplicated group (37 cases) were 95.65 and 96.32% in the proximal and distal segments, respectively, whereas in the complicated group (three cases), mean value were 89 and 87% in the proximal and distal segments, respectively (Table 9).

PO absent signals in either proximal or distal bowel ends (either not detected or not accessible) in relation to bowel ischemia that predisposes to complications are shown in Tables 10 and 11. The accuracy of proximal PO readings in prediction of latter ischemic changes is 97.5%, whereas in the distal bowel PO readings, its accuracy in prediction of ischemic complications is 94.44%

In the proximal bowel, PO readings has a sensitivity of 66.67% and specificity of 100% in prediction of further ischemic complications. However, in the distal segments, PO readings showed sensitivity of 0% and specificity of 100%, as shown in Table 12.

Discussion

During operation, distinction of viable from nonviable intestine is not always easy. Frequently, a bowel loop that looks healthy and is left in the abdomen will develop gangrene within 1 or 2 days, hence the

Table 9 Complications in relation to both proximal and distal pulse oximeter saturation readings

Complication	Saturation proximal	Saturation distal
No		
Mean	95.65	96.32
N	37	34
SD	3.093	1.870
Minimum	83	93
Maximum	99	99
Median	96.00	97.00
Yes		
Mean	89.00	87.00
N	1	2
SD		16.971
Minimum	89	75
Maximum	89	99
Median	89.00	87.00
Total		
Mean	95.47	95.81
N	38	36
SD	3.236	4.027
Minimum	83	75
Maximum	99	99
Median	96.00	97.00

Table 10 Pulse oximetry proximal-absent signals (bowel ischemia cross-tabulation)

	Bowel ischemia		
	Negative	Positive	Total
PO proximal-absent signals			
Negative			
Count	37	1	38
% within PO proximal-ischemia	97.4	2.6	100.0
% within bowel ischemia	100.0	33.3	95.0
Positive			
Count	0	2	2
% within PO proximal-ischemia	0.0	100.0	100.0
% within bowel ischemia	0.0	66.7	5.0
Total			
Count	37	3	40
% within PO proximal-ischemia	92.5	7.5	100.0
% within bowel ischemia	100.0	100.0	100.0

PO, pulse oximetry.

Table 11 Pulse oximetry distal-absent signals (bowel ischemia cross-tabulation)

	Bowel ischemia		
	Negative	Positive	Total
PO distal-absent signals			
Negative			
Count	34	2	36
% within PO distal-ischemia	94.4	5.6	100.0
% within bowel ischemia	100.0	100.0	100.0
Total			
Count	34	2	36
% within PO distal-ischemia	94.4	5.6	100.0
% within bowel ischemia	100.0	100.0	100.0

PO, pulse oximetry.

policies of a second-look surgery. Waiting for fixed color changes to develop may take a long time, and actually, very precious time is wasted.

For all the above, proper intraoperative assessment of bowel perfusion which unfortunately is done frequently on subjective basis is required. Clinical findings, such as color, pulsation, temperature, and/or peristalsis, are the metrics that currently guide the extent of bowel resection in the presence of ischemia. Unfortunately, clinical findings alone often lead to extensive bowel resection or anastomotic failure [5]. The incidence of anastomotic leak after gastrointestinal tract surgery in this situation has been reported to be 2.7–7.6% in recent studies [6].

Numerous techniques, including Doppler ultrasonography [7,8], laser tissue blood flowmetry [9–15], near infrared spectroscopy, charged-couple device microscopy, PO, and fluorescence angiography using fluorescein injection have been evaluated for clinical use during bowel surgery [16].

Horgan and Gorey [1] suggested that the technique must have ready availability preferably in every operating theater dealing with abdominal emergencies. Moreover, the necessary equipment must not be cumbersome or require specialized personnel, adding to this, the method must be accurate with a minimum of false-negative results, and more importantly, few false positive results. A false-negative result leaves in situ nonviable bowel. On the contrary, a false-positive assessment of bowel viability results in the resection of potentially recoverable intestine, which is lost forever. The technique must also be objective, reproducible, and cost effective [1].

For the aforementioned reasons, the PO has emerged as a new technique which fulfilled the aforementioned criteria. It is to be known that in 1995, Tollefson *et al.* [17] stated in 'Intraoperative determination of intestinal viability by pulse oximetry' the utility of trans-serosal photoplethysmographic PO to assess intestinal viability intraoperatively using an experimental canine model and only in 1988, Ferrara *et al.* [18] stated in 'Surface oximetry, a new method to evaluate intestinal perfusion' the PO uses as a commercially available instrument to assess tissue oxygenation and arterial flow, which is rapid, reproducible, and noninvasive method.

In our study, it is the first time to use sterilizable portable wireless digital PO on human intestine

Table 12 Sensitivity, specificity, and accuracy of pulse oximetry proximal and distal readings in detection of bowel ischemia

Item	TP	FN	TN	FP	Sensitivity	Specificity	PPV	NPV	Accuracy
PO proximal	2	1	37	0	66.67	100.00	100.00	97.37	97.50
PO distal	0	3	34	0	0.00	100.00		94.44	94.44

FN, false negative; FP, false positive; NPV, negative predictive value; PO, pulse oximetry; PPV, positive predictive value; TN, true negative; TP, true positive.

during surgeries. It included 40 patients, in which fluorescein, a well-known standard technique, was added to the first 10 cases to validate the newer technique of the PO. Comparison between both modalities showed that there is a large agreement between fluorescein and PO as they work side by side. The PO shows high SpO_2 readings when the fluorescein fluorescence was detected. In the other 30 patients, we just used the PO to assess the viability of the intestine where it showed good results.

After validation of the PO with the fluorescein, we found that PO readings in the proximal and distal intestinal segments in relation to complications were helpful to a large extent (*P* value in the proximal segment 0.004 and distal segment *P* value is 1.00). The accuracy of proximal PO readings in prediction of latter ischemic changes was 97.5% with sensitivity and specificity of 66.67 and 100%, respectively, whereas in the distal bowel PO readings, its accuracy in prediction of ischemic complications was 94.44%, with sensitivity and specificity of 0 and 100%, respectively. The mean values recorded for the patients who had no complications in the follow-up period were SpO_2 of 95.65 and 96.32% in proximal and distal segments, respectively, whereas in the patients who experienced complications, the mean recorded values in the proximal and distal segments were SpO_2 of 89.00 and 87.00%, respectively. Up till now, there is no consensus on the minimal PO reading values required during surgery on intestinal segments to ensure adequate perfusion. These findings would recommend that we should have PO readings above 90% of SpO_2 in both proximal and distal segments to guarantee proper vascularization of the intestine to avoid later complications on condition that other requirements for successful intestinal anastomosis are fulfilled. Another recommendation is to have high SpO_2 readings in both proximal and distal segments, as in our study, the complications (three cases) occurred when one segment or both showed no SpO_2 readings or readings below 90% in either of them.

Conclusion and outcomes

In conclusion, we can rely on the SpO_2 of the wireless sterilizable PO in the assessment of the bowel viability during surgery, which should be more than 90% in both proximal and distal segments. Moreover, the PO device is safe; is portable; is not sophisticated, which can be used easily by surgeons; takes less time to assess the intestinal viability; and is very cost effective, as one device can be used in multiple patients.

Limitations

Finally, as any research study done before, we acknowledge that our study may have some limitations and shortages. The relatively low sample size with limited cases of strangulated or ischemic bowel. This may explain some of the statistically nonsignificant values in the study. Another limitation in our study was the presence of more than one colorectal surgeon, involved in the surgeries of ischemic bowel, with different levels of experience and technical and learning curves which might have influenced the results of the present study. Sometimes difficult access to the distal bowel segments as in narrow pelvis or like that encountered during laparoscopic surgeries may affect our results. Lastly, paucity of published studies done in these cases to build up upon it and to use it as a references may be added to the limitations faced in our study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Horgan PG, Gorey TF. Operative assessment of intestinal viability. Surg Clin North Am 1992; 72:143–155.

2 Holmes NJ, Cazi G, Reddell MT, Gorman JH, Fedorciw B, Semmelow JL, *et al.* Intraoperative assessment of bowel viability. J Invest Surg 1993; 6:211–221.

3 Toens C, Krones CJ, Blum U, Fernandez V, Grommes J, Holezl F, *et al.* Validation of IC-VIEW fluorescence videography in a rabbit model of mesenteric ischaemia and reperfusion. Int J Colorectal Dis 2006; 21:332–338.

4 Willis S, Hölzl F, Krones CJ, Tittel A, Shumpelick V. Evaluation of anastomotic microcirculation after low anterior rectal resection: an experimental study with different reconstruction forms in dogs. Tech Coloproctol 2006; 10:222–226.

5 Kirkpatrick ID, Kroeker MA, Greenberg HM. Biphasic CT with mesenteric CT angiography in the evaluation of acute mesenteric ischemia Initial experience. Radiology 2003; 229:91–98.

6 Karliczek A, Harlaar NJ, Zeebregts CJ, Wiggers T, Baas PC, van Dam GM. Surgeons lack predictive accuracy for anastomotic leakage in gastrointestinal surgery. Int J Colorectal Dis 2009; 24:569–576.

7 Ambrosetti P, Robert J, Mathey P, Rohner A. Left-sided colon and colorectal anastomoses: Doppler ultrasound as an aid to assess bowel vascularization – a prospective evaluation of 200 consecutive elective cases. Int J Colorectal Dis 1994; 9:211–214.

8 Dyess DL, Bruner BW, Donnell CA, Ferrara JJ, Powell RW. Intraoperative evaluation of intestinal ischemia: a comparison of methods. South Med J 1991; 84:966–969.

9 Humeau A, Steenbergen W, Nilsson H, Stromberg T. Laser Doppler perfusion monitoring and imaging: Novel approaches. Med Biol Eng Comput 2007; 45:421.

10 Nakatsuka M. Assessment of gut mucosal perfusion and colonic tissue blood flow during abdominal aortic surgery with gastric tonometry and laser Doppler flowmetry. Vasc Endovascular Surg 2002; 36:193–198.

11 Redaelli CA, Schilling MK, Carrel TP. Intraoperative assessment of intestinal viability by laser Doppler flowmetry for surgery of ruptured abdominal aortic aneurysms. World J Surg 1998; 22:283–289.

12 Vignali A, Gianotti L, Braga M, Radaelli G, Malvezzi L, Di Carlo V. Altered microperfusion at the rectal stump is predictive for rectal anastomotic leak. Dis Colon Rectum 2000; 43:76–82.

13 Seike K, Koda K, Saito N, Oda K, Kosugi C, Shimizu K, Miyazaki M. Laser Doppler assessment of the influence of division at the root of the inferior mesenteric artery on anastomotic blood flow in rectosigmoid cancer surgery. Int J Colorectal Dis 2007; 22:689–697.

14 Singh DB, Stansby G, Bain I, Harrison DK. Intraoperative measurement of colonic oxygenation during bowel resection. Adv Exp Med Biol 2009; 645:261–266.

15 Singh DB, Stansby G, Harrison DK. Assessment of oxygenation and perfusion in the tongue and oral mucosa by visible spectrophotometry and laser doppler flowmetry in healthy subjects. Adv Exp Med Biol 2008; 614:227–233.

16 Matsuil A, Winer H, Laurencel J, Frangionil V. Predicting the survival of experimental ischaemic small bowel using intraoperative near-infrared fluorescence angiography. Br J Surg 2011; 98:1725–1734.

17 Tollefson DF, Wright DJ, Reddy DJ, Kintanar EB. Intraoperative determination of intestinal viability by pulse oximetry. Ann Vasc Surg 1995; 9:357–360.

18 Ferrara JJ, Dyess DL, Lasecki M, Kinsey S, Donnell C, Jurkovich GJ. Surface oximetry. A new method to evaluate intestinal perfusion. Am Surg 1988; 54:10–14.