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ORIGINAL SCIENTIFIC REPORT

Changes in the Surgical Management of Parastomal Hernias Over 15 Years: Results of 135 Cases

Gernot Köhler[1,2,3,5] · Franz Mayer[5] · Helwig Wundsam[1,2,3] · Rudolf Schrittwieser[4] · Klaus Emmanuel[1,2,3] · Michael Lechner[5]

Abstract

Background Over the years, various open and laparoscopic approaches toward the repair of parastomal hernias (PSH) have been described. The variety of published techniques itself can be seen as an indicator for the often low level of satisfaction reached with the surgical procedures.

Methods From January 1999 to January 2014, we assessed all cases of PSH repair performed at the three participating surgical departments in a retrospective analysis. The results were evaluated with regard to different surgical techniques focusing on complications and recurrences.

Results One hundred and thirty-five individuals could be included in the analysis. They were operated on with eight different surgical techniques. Laparoscopic procedures were carried out in 46.7 % (63/135) of the cases. Median follow-up was 54 months (12–146 months). We found 44 cases of recurrence (32.6 %) and 24 (17.8 %) of the patients experienced perioperative complications and 12 of them needed to return to theater. Fourteen of the 135 patients (10.4 %) were operated as emergency cases which were associated with a mortality of 28.6 % (4/14). In case of elective PSH repair, no mortality occured.

Conclusion The results achieved by direct suture or the use of incised flat meshes for the repair of PSH were poor with these procedures having unacceptably high recurrence rates. With regard to the latter ostomy revision through three-dimensional funnel-shaped meshes and the laparoscopic sandwich technique showed the best results. Emergency procedures were linked to a dramatic increase in morbidity and mortality ($p < 0.001$).

Gernot Köhler and Franz Mayer have contributed equally to the publication.

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Introduction

Parastomal hernias (PSH) are incisional hernias in direct topographic relation to an artificial opening for the bowels [1] and their high incidence can be explained by the fact that ostomy formation requires the creation of a full-thicknes defect of at least 3 cm in diameter within the abdominal wall [2]. The wide range of published incidence rates for PSHs reflect differences in definition, ostomy types evaluated, and duration of postoperative evaluation periods [1, 3]. Consequent follow-up with computed tomography (CT) reveals an actual PSH incidence of around 80 % [4]. Symptomatic PSHs that warrant surgical repair can in most cases be diagnosed clinically and are usually evident during Valsalva's maneuver, when patients

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are standing upright during physical examination [5]. In general, terminal colostomies show the highest rates of PSHs [3, 5] and these mostly occur during the first 2 years after stoma formation [3]. PSHs are categorized according to their size, location, radiological appearance, or the content of their sacs. The clinical relevance of these grading systems and their value for the further management of these hernias is, however, under debate [6, 7]. Whether or not PSHs should be repaired depends largely on the patient's symptoms. PSHs can cause a wide array of problems and the number of patients affected by the condition may well be underestimated. The range of complications comprises para-stomal skin irritations, permanent leakage at the base of the stoma pouch, unspecific abdominal discomfort or back pain due to a partial prolapse of the viscera, and incarceration and strangulation of bowel [1, 3].

Looking at data collected in Danish and U.S-registries, the risk of incarceration and strangulation appears higher than generally assumed and the threshold for elective repair of PSH should be lowered in order to avoid emergency procedures with drastically increased morbidity and mortality [8, 9]. In recent years, various new surgical techniques based on suture repair or mesh augmentation have been developed for the operative treatment of PSHs. Techniques involving mesh implants can be further specified according to the surgical approach (open or laparoscopic), the type of implant (biological or synthetic), and its position relative to the layers of the abdominal wall (onlay, sublay, or intraperitoneal). Recently three-dimensional, funnel-shaped meshes have become available. Initially developed for the prevention of PSHs [10], they are also suitable for their repair [11]. Which of the current techniques provides highest patient safety and the lowest rate of complications or recurrence is a controversial matter.

Materials and methods

We conducted a retrospective analysis of all patients who underwent surgical repair of PSHs at one of the three surgical departments participating in the trial between January 1st 1999 and January 31st 2014. All patients with a reversal of the ostomy in the same procedure were excluded. All elective and emergency cases of PSH repair with the presence of a permanent terminal ostomy were included and investigated. Co-existing incisional hernias were not a reason for exclusion from the study. For the evaluation of data, the Herniamed® [12] register has been used since 2010. In addition to this data and before that point in time electronic patient files from the hospitals' archives (SAP®-software and MCC®-Meierhofer clinical competence GmbH) as well as the files of the respective stoma clinics were analysed. Indications for surgery were abdominal pain, bowel obstruction, incarceration or strangulation, marked progression in size, visceral prolapse, and impossibility to manage the ostomy due to local deformity related to a PSH. In order to further define the indication and for accurate pre-operative planning, CT scans in supine position and during Valsalva's maneuver were obtained prior to surgery. The subsequent evaluation of data was condensed to essential demographic and disease specific parameters and to relevant accepted risk factors. PSHs were categorized according to the European Hernia Society's (EHS) classification [7].

The three participating surgical departments maintain a close co-operation with regard to hernia surgery and apply the same surgical standards in these procedures. The decision as to which operation was performed was at the discretion of the surgeon. From 1999 to 2002, suture repairs were performed. From 2002 to 2007, preferably open mesh repairs (onlay, sublay) were carried out. Since 2007, the default option ist to perform procedures laparoscopically [evolution from keyhole to Sugarbaker to sandwich to three-dimensional (3D) meshes]. We currently do the operations with sandwich technique (Authors F.M and R.S) or a 3D mesh (Author G.K.) in all patients unless there is a specific contraindication for laparoscopy or mesh repair.

Pre-operative bowel preparation was carried out with 1–2 L of a saline solution or with enemas 1 day before the operation. Perioperatively all patients received intravenous antibiotic prophylaxis. In cases of open surgery, antibiotic treatment was continued for a minimum of 3 days after the operation. Due to the variability of operating times once under general anesthesia, all patients received an indwelling urinary catheter. Additionally, a nasogastric tube was placed in case of laparoscopic procedures. The first trocar was always placed in open (Hasson) technique and well away from the ostomy. Patients were operated on in supine position with both arms at their body, and the laparoscopic unit was routinely positioned opposite the trocars—i.e., on the side of the ostomy.

Short description of the surgical techniques used in this series

(1) *Suture repair of the hernia defect* After a curved incision of 7–15 cm well lateral of the ostomy's base plate area, the anterior sheet of the rectus sheath was repaired with slowly absorbable mono- or poly-filament USP (United States Pharmacopeia) 0 sutures.

(2) *Onlay mesh repair* An identical approach was used for this technique and after suture repair of the anterior rectus sheath a 10×15 cm^2 implant was

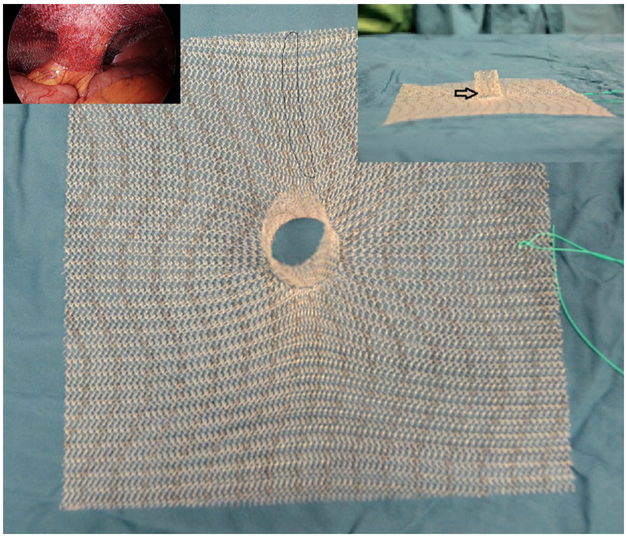

Fig. 1 **a** Three-dimensional funnel mesh on aerial and lateral view. **b** Laparoscopic view on the finally placed funnel mesh around the ostomy in intraperitoneal (underlay) position

positioned onto the fascia. Meshes used were either partially absorbable (polyglactin/polypropylene-Ethicon®, Vypro or Vypro II), monocryl/prolene (Ethicon®,Ultrapro) or polypropylene (Covidien®, Parietene). They were routinely incised in a swallow tail shape and placed around the ostomy, so that the tail parts could be positioned at the lateral side of the bowel. They were then sutured to the underlying fascia under direct visual control with non-absorbable monofilament.

(3) *Sublay repair* was performed after a median laparotomy. After adhesiolysis, resection of the sac and reduction of the hernia, the rectus sheath was opened in the midline on the side of the ostomy and its posterior sheath was mobilized from the muscle. Partially absorbable or polypropylene meshes were incised and positioned with their intact structure between the „linea semilunaris“flanking the ostomy. Between the ostomy and the midline incision the swallow tail flaps of the meshes eventually overlapped on the medial side of the ostomy. The meshes were carefully fixated with non-absorbable monofilament sutures on the posterior rectus sheath and/or stuck with fibrin glue (Baxter®, Tisseel) below the arcuate line. For anatomical reasons mesh size was usually limited to 7×10 cm^2.

(4) *Keyhole-repair* was commenced in 2007 and was the first laparoscopic technique evaluated in the study. A prefabricated polyester implant with collagene coating (Covidien®, parietex composite, parastomal mesh) of 15×15 cm^2 with a 35 mm diameter central opening was used. The mesh was fixated with non-absorbable transfascial sutures and absorbable or non-absorbable staples (Covidien®, Absorbatack, Protack).

(5) Laparoscopic *Sugarbaker repair* was carried out with a 20 cm diameter, circular parastomal mesh without central opening (Covidien®, parietex composite) which was not incised. The polyester implant is equipped with a completely adhesion barrier of a collagen film toward the abdominal cavity (visceral side) and with a central strip-type adhesion barrier protecting the diverted bowel in the area of contact on the parietal side.

(6) *Sandwich* technique was the next evolutionary step and it was used since 2011 when keyhole- and Sugarbaker repair were combined. Macroporous meshes with a two-component structure of polypropylene (on the parietal side) and polyvinylidene fluoride (on the visceral side) were used (Dahlhausen®, Dynamesh IPOM), and the procedure was carried out exactly as first described by D. Berger [13].

(7) Since 2012 3*D*, *funnel-shaped meshes* have been used for the surgical repair of PSHs. We aimed to re-implant the ostomy on the same side in its original location once the diverted bowel segment had been passed through the funnel mesh in order not to create another abdominal wall defect. Furthermore, we averted cutting the implant with consequent destruction of the mesh integrity. After laparoscopic adhesiolysis, the adjacent skin of the ostomy was sparingly excised from outside the abdomen, and the bowel loop was temporarily closed with a running suture and placed into the abdominal cavity. The hernia content was then reduced easily and safely and the entire hernia sac was then resected under direct view to prevent subsequent seroma formation. The diverted bowel was then guided through the pre-existing stoma hole of the abdominal wall again. Then the bowel was guided through the central funnel of the mesh outside of the abdomen (Dahlhausen®, Dynamesh IPST). Meshes of 15×15 or 16×16 cm^2 with a 2 or 3 cm diameter central opening and a uniform funnel length of 2.5 cm were used. The implant was then manually transferred into the peritoneal cavity with the funnel facing away from the abdominal wall toward the viscera. The additional opportunity for a suture repair of the fascia to narrow the stoma-opening at the PSH site with slowly absorbable monofilament sutures USP 0 was routinely used. Laparoscopy was then continued, the implant was positioned inside the abdomen with atraumatic graspers and fixated to the abdominal wall with absorbable strap devices (Ethicon®, Securestrap). The mesh is mostly centered

Table 1 Demographic and disease characteristics

Number of patients	135	%
Age (years)	68.4 ± 26.1	
BMI (kg/m^2)	25.4 ± 6.8	
Sex ratio female/male	62 versus 73	45.9 versus 54.1
Oncological versus non malignant disease	117 versus 18	86.6 versus 13.4
EHS Classification of PSH*		
1	35	25.9
2	52	38.5
3	26	19.3
4	22	16.3
EHS 1 and 3 (without concomitant incisional hernia) versus EHS 2 and 4 (with concomitant incisional hernia)	61 versus 74	45.2 versus 54.8
Simultaneous repair of incisional hernias	63/74	85.1
Type of ostomy		
Colostomy	120	88.9
Ileostomy	10	7.4
Urostomy	5	3.7
Ostomy localisation left versus right abdominal side	117 versus 18	86.7 versus 13.3
PSH primary versus recurrence**	104 versus 31**	77 versus 23
Repair: laparoscopic versus open	63 versus 72	46.7 versus 53.3
Conversions (laparoscopic to open surgery)	9/72	12.5
Hospital stay (days): laparoscopic versus open	6.3 versus 5.5	
Risk factors		
Obesity BMI > 30	24	17.8
COPD (chronic obstructive pulmonary disease)	19	14.1
Diabetes mellitus	17	12.6
Steroid use	3	2.2
Smoker	49	36.3
2 or more risk factors	37	27.4

* EHS classification of parastomal hernias [11] (small is ≤5 cm, *cIH* concomitant incisional hernia); *type I* small PSH without cIH, *type II* small PSH with cIH, *type III* large PSH without cIH, *type IV* large PSH with cIH

** Eight from overall 31 repairs of recurrent PSH were required after direct suture repair and 23 after different mesh-based repairs

by the diverted bowel and no transfascial sutures were used. When needed in the presence of a concomitant incisional hernia of the midline a second and suitably sized flat mesh was laparoscopically placed in IPOM position. Finally, the diverted bowel was shortened outside the abdomen, if necessary to reduce an often present prolapse and the stoma was refixed at its initial location with mucocutaneous interrupted sutures. Figure 1a give top- and side-view of the mesh implant and funnel. Figure 1b displays the laparoscopic view of the implant in its final position.

(8) In case of an open surgical approach, the same implants could be used. After a midline, laparotomy open adhesiolysis at the abdominal wall and in the area around the diverted bowel was performed with reduction of hernia contents. The ostomy was then again sparingly excised at skin level and temporarily closed with sutures. After resection of the hernia sac, a suitable implant size right up to 25 × 25 cm^2 (maximum size) was then equipped with non-absorbable sutures at intervals of 2 cm on the side of the implant that would eventually face the contralateral side of the midline incision to provide an overlap over the midline incision in open intraperitoneal position. After the bowel was guided through the funnel and returned to the ostomy site, the mesh was stapled to

Table 2 Outcome parameter and follow-up

Number of patients	135	%
Perioperative overall morbidity (including non-surgical complications)	29	21.5
Repair: emergent	14	10.4
Elective	121	89.6
Perioperative mortality (including non- surgical complications)	4	2.9
Surgical complications overall (intra and postoperative <30 days)	24 from 135	17.8
Intraoperative complications	4 from 24	16.7
Postoperative surgical complications	20 from 24	83.3
Complications requiring reoperation (Clavien–Dindo ≥3b)	12 from 24	50
Clavien–Dindo classification of 20 surgical Complications ≥3a*		
3a	8	
3b	10	
4	2	
5	0	
Unplanned readmissions <30 days after dismissal	14	10.4
Mesh-based repairs	110	81.5
Mesh infections	4	2.9
Mesh removal	2	1.8
Recurrence	44	32.6
Recurrence requiring Reoperation	28 from 44	63.6
Recurrence <2 years postoperatively	38 from 44	86.4
Length of hospital stay (days) median	6 (range 2–26)	
Follow-up rate (1 year postoperatively)	111	82.3
Follow-up (months) median	54 (range 12–146)	
CT scan 1 year postoperatively	99	73.3

* Clavien–Dindo classification of surgical complications [23]

the abdominal wall with absorbable tacks on the side of the stoma. Due to the paramedian position of most ostomies, the midline could be reinforced with the flat part of the implant in open IPOM technique and an overlap of at least 5 cm was reached in these cases. The sutures previously attached to the implant's edge were then led through the contralateral abdominal wall (with regard to the ostomy) with the help of a suture catcher (Covidien®, Endoclose) but tied only after the midline incision (anterior rectus sheaths) was closed to allow for ideal contact of the mesh to the peritoneum and to avoid folding and wrinkles in the implant. Eventually, excessive bowel length was reduced as necessary and the ostomy was completed with absorbable sutures to the skin.

Follow-up

After PSH repair all oncology patients were included in the hospitals' aftercare programs for a period of 5 years. This routine follow-up scheme comprises clinical, radiological and laboratory examinations, and studies. CT scans were usually obtained 1 year after the operation and were repeated when necessary. All other patients were followed up in case of complaints. In addition from 2010 onward, all patients were followed up in accordance with the Herniamed® register's regulations—i.e., postoperatively, after one, and (scheduled) 5 and 10 years. Recurrence, chronic pain, and local complications were recorded.

Statistical considerations

Statistical analysis was performed using SPSS-Statistical-Analysis Software Version 20 (SPSS Inc. Chicago, IL, USA). The Tamhane's T2 multiple comparison test was used to determine differences between the different surgical techniques regarding recurrence and complications. In some cases, descriptive statistics were used. Probability recorded as $p < 0.05$ was regarded as statistically significant.

Results

Demographic and disease characteristics

Over the study period, there were 135 patients who had PSH repaired. Table 1 describes the detailed demographics

Table 3 Surgical technique- related complications and recurrences

Type of repair	Overall repairs 135 (100 %)	Overall complications: 24 reoperations: (12)	Median follow-up 54 months	Overall recurrence: 44 reoperation: (28)	Median operative time (103 min)	Median length of stay (6 days)
Fascial (sutures)	25 (18.5)	4 (3)	62	10 (6)	62	6.1
Onlay (mesh)	22 (16.3)	5 (4)	58	12 (6)	74	6.4
Sublay (mesh)	20 (14.8)	3 (1)	46	9 (8)	130	6.8
Laparoscopic keyhole	22 (16.3)	4 (2)	38	10 (6)	94	5.3
Laparoscopic Sugarbaker	4 (3)	1 (1)	32	2 (2)	100	5.7
Laparoscopic sandwich	21 (15.5)	4 (1)	28	1 (0)	154	5.4
Laparoscopic same-side stoma relocation through funnel mesh	16 (11.8)	2 (0)	22	0	84	5.6
Open same-side stoma relocation through funnel mesh	5 (3.8)	1 (0)	16	0	128	6.6

and disease characteristics of these patients. Thirty-one cases were performed for recurrences after previous repair. The rate of laparoscopic procedures has been constantly increasing and since 2007 most approaches toward PSH repair were initially made that way. Laparoscopic surgery was attempted in patients who had multiple abdominal procedures which is partially responsible for the high rate of conversion from laparoscopic to open PSH repair. Laparoscopy was attempted in a total of 72 cases. Conversion was required for nine of these cases which were then classified in the "open repair"group. Concomitant incisional hernias (EHS 2 and 4) [7] were found in 54.8 % (74 cases) and could be repaired in a single step procedure together with the PSH in 63 of 74 cases (85.1 %). The high rate of additional incisional hernia repair during laparoscopic procedures for PSH (41/63, 65 %) results from the excellent view of the abdominal wall after laparoscopic adhesiolysis and the then easily visible hernias that would otherwise remain undetected. As a consequence, these defects were treated together with the PSHs.

Morbidity, mortality, complications, and recurrences

These parameters are outlined in Table 2. Of these 135 repairs, 14 were emergencies and the rest were elective. There were four mortalities in this series and all of these were in patients having an emergency repair ($p < 0.001$). There were 24 patients who had major complications. We noted four intraoperative complications: three patients had intraoperative bowel injuries: one of which affected the colon, two the small intestine. The patient who sustained a colonic injury underwent a conversion to open surgery with suture repair of the bowel and the hernia. The patients who had the small bowel injuries were treated with meshes for PSH repair after bowel reparation: one operation was finished in the laparoscopic keyhole technique, the other one was converted and an open IPST®-reinforced stoma repair was performed. The fourth adverse event was a trocar-related injury of the left iliac artery. The operation was converted immediately, the vessel was sutured and the PSH was treated with an open sublay procedure.

The twenty postoperative complications were rated according to the Clavien–Dindo classification [14] (Table 2). An intraoperative unrecognized full thickness lesion of the small bowel and a thermal injury caused by electrocautery with a resulting postoperative small bowel perforation on postoperative day three occurred in two cases (Clavien–Dindo 4) after laparoscopy. An open revision with small bowel resection and mesh removal was required in both cases, and an abdominal vacuum-assisted system (VAC) was applied. The fascia defect was closed within 2 weeks. Two mesh infections occurred after open onlay and sublay repair. The mesh removals were required as a result of large infected hematomas on day 4 and 7 after surgery (Clavien–Dindo 3b). The remaining eight revisions under general anesthesia (Clavien–Dindo 3b) became necessary after surgical site infections at the ostomy site (4), and at the midline incision (4). The remaining eight adverse events (Clavien–Dindo 3a) involved disturbed wound healing, local infections, seromas, or need for drainage and were controlled by local wound management. The two subcutaneous seromas after laparoscopically assisted 3D-ostomy repositioning were drained because of their size and local signs of infection. The overall recurrence rate in this series was 32.6 % (44/135).

Table 4 Significant differences between the different surgical techniques regarding recurrence rates

Comparison between surgical techniques	Fascial suture	Onlay mesh	Sublay mesh	Lap. keyhole	Lap. Sugarbaker	Lap. Sandwich	Lap. funnel mesh relocation	Open funnel mesh relocation
Fascial suture	x	1	1	1	1	0.084	*0.015*	*0.015*
Onlay mesh	1	x	1	1	1	0.007	*0.02*	*0.02*
Sublay mesh	1	1	x	1	1	0.086	*0.024*	*0.024*
Lap. keyhole	1	1	1	x	1	*0.05*	*0.012*	*0.012*
Lap. Sugarbaker	1	1	1	1	x	0.999	0.996	0.996
Lap. Sandwich	0.084	0.007	0.086	*0.05*	0.999	x	1	1
Lap. funnel mesh relocation	*0.015*	*0.002*	*0.024*	*0.012*	0.996	1	x	1
Open funnel mesh relocation	*0.015*	*0.002*	*0.024*	*0.012*	0.996	1	1	x

Comparison between surgical techniques regarding recurrence rate (Tamhane's T2 multiple comparison test)

$p < 0.05$ regarded as statistically significant values are given in italics

Procedure-specific complication and recurrence rates

Procedure-specific recurrence and complication rates are shown in Table 3. The highest success rate was in those patients having a 3D mesh repair (no recurrence) and the lowest was in patients who had an onlay mesh repair (54.5 % recurrence: 12/22). As for recurrence rates, open and laparoscopic 3D mesh repair showed significantly better results than direct sutures ($p = 0.015$), onlay ($p = 0.02$), sublay ($p = 0.024$), or laparoscopic key-hole repair ($p = 0.012$). The sandwich technique tended to give better results than direct sutures ($p = 0.084$), or sublay meshes ($p = 0.086$) and was associated with significantly lower recurrence rates than onlay ($p = 0.007$) and key-hole repair ($p < 0.05$) (Fig. 2; Table 4). Isolated hernia specific risk factors showed no significant influence. The methods described showed no statistically significant differences in complication rates.

Follow-up

Adequate follow-up rates of 82.3 % (111/135) were reached (1 year postoperatively), and overall median follow-up time was 54 months (12–146 months). Twenty-four patients were lost to follow-up: 16 were known to have demised, 8 could not be contacted or refused to participate in follow-up interviews and examinations.

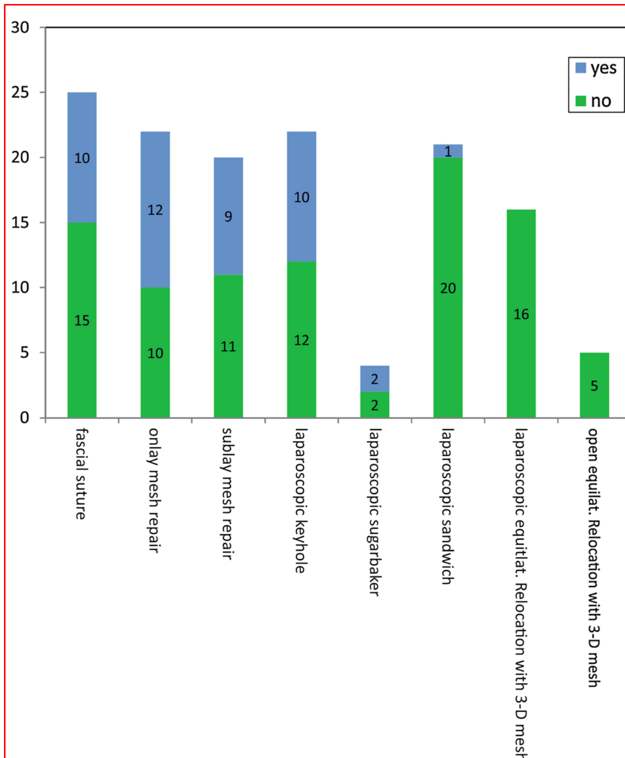

Fig. 2 Surgical techniques and recurrence rate for parastomal hernia repair (recurrence: *blue* yes, *green* no)

Discussion

With regard to PSHs, we not only need to identify patients who benefit from hernia repair but also have to define the best possible technique for these often complex cases. It is worth noting that even in the presence of debilitating clinical symptoms PSH patients often remain without adequate treatment because the commonly available surgical strategies are associated with high complication rates [15]. However, the life time risk for incarceration or strangulation of at least 10 % of patients not undergoing PSH repair appears generally to be underappreciated [8, 9]. In our own series, we also observed emergency procedures in 10.4 %. We perceived a frequent crossover of initially asymptomatic patients to the symptomatic group. Over time the hernia's size tended to increase and the growing volume of the resulting visceral prolapse lead to abdominal discomfort and to restrictions in physical ability. Over the years, a number of methods for the repair of PSHs was described, which indicates that the available surgical strategies were unsatisfying [15]. We distinguish between open (local access or laparotomy) and laparoscopic repairs and between suture- and mesh-based repairs. Direct suture repair of the fascia gives direct access to the hernia and avoids a laparotomy, but it is associated with unacceptably high recurrence rates [16]. If direct fascial repair is such a poor operation, why did we do it in the first place? Until 2002, we tried to avoid meshes because we feared infections. After the year 2002, these operations were only performed in patients in whom mesh placement was deemed too risky. Interestingly, in our series incised mesh-based repairs did not give better results than fascia closure. It is impossible to sufficiently reinforce the ostomy's edge areas with a flat incised mesh that has a central defect. An improvement of the surgical results could be achieved with 3D meshes and the combination of keyhole and Sugarbaker repair (Sandwich technique). Relocation of the ostomy to the other side of the abdominal wall has multiple disadvantages: It demands a laparotomy, reduces the stability of yet another quadrant of the abdominal wall and leaves an additional weak spot in the initial stoma position. Simple repositioning of the ostomy in its original place without mesh augmentation also can not be recommended due to high recurrence rates [16]. Through reinforcement of the parastomal area by augmentation with a 3D funnel-shaped mesh, however, this type of repair could face a renaissance [11]. Techniques that involve mesh implants are onlay-, sublay, and intraperitoneal repair (keyhole, Sugarbaker, sandwich and funnel meshes). In the case of onlay repair, the access is a local one lateral from the ostomy, and care must be taken to incise the skin well away from the later position of the ostomy pouch to avoid complications in the management of the stoma. A sublay augmentation of the posterior sheath of the rectus muscle demands a midline laparotomy, and for anatomic reasons, usually only little overlap over the hernia defect can be achieved in this compartment. Intraperitoneal mesh placement can be reached either through laparotomy or laparoscopically. The Sugarbaker technique appears to lead to better results than the keyhole repair [17]. The lateral peristomal region must be understood as the main weak spot in Sugarbaker's repair because it cannot be adequately reinforced with the mesh covering the deviated bowel. Furthermore irrigation is not possible due to the bowel lateralisation. We cannot comment on this fact, since we abandoned the Sugarbaker technique after only four cases due to two recurrences within 6 months after the operation in favor of Berger's sandwich technique [13] that was adopted after the authors were assisted by the inventor of the procedure in teaching operations. We found that the necessary length of deflected bowel is occasionally difficult to define during the procedure but did not observe any cases of kinking or bowel obstruction neither in Sugarbaker nor in sandwich repairs. In accordance with published literature that reports recurrence rates of 36–46 % in larger studies [18, 19], our own results after keyhole repair were poor. It is obviously impossible to sufficiently reinforce the ostomy's rim, i.e., the border zone between the more resistant abdominal wall and the soft bowel with a flat incised mesh that has a central defect. These implants instead predominantly guard the surrounding area oft he abdominal wall that does not necessarily need any reinforcement. The same is true for sublay- and onlay repair, both of which also use incised flat meshes only in a different layer of the abdominal wall. Only a few trials focused on the role of sublay repair for PSHs. Most of them are of limited validity due to small patient numbers or short follow-up periods [20]. Since the isolated use of incised flat meshes does not give encouraging results, the combined Sugarbaker and keyhole (i.e., sandwich) technique [13] offers an interesting alternative. Two things are paramount for this procedure: the diameter of the central defect in the flat mesh should not be more than 1.5 cm which prohibits the use of prefabricated devices with defect diameters of 3 or more cm. Secondly, the length of the deviated bowel under the 'Sugarbaker' mesh should be at least 5 cm to allow for adequate coverage of the hernia defect. Drawbacks of the sandwich repair are technical difficulties in mesh placement and the large amount of foreign material necessary for the procedure. It is currently unclear to what extent the two overlapping meshes can be integrated into the abdominal wall or how much—and what type of—adhesion formation they cause. It is also not always possible to correct a concomitant prolapse of the ostomy and the edges of the keyhole mesh may erode into the bowel in the long run. Both factors will warrant further observation.

We developed a new technique for the repair and prevention of PSH formation in 2012 to avoid the disadvantages of the various methods [11]. Repositioning of the diverted bowel through a 3D funnel mesh gives several significant advantages: The implants can be used either in open procedures or with laparoscopic assistance and they cover the inner margin of the hernia defect with their funnel-shaped part. The intraperitoneal position allows for wide overlap of the defect. If necessary even the midline incision can be reinforced with the implant's flat part. The elastic and rounded mesh tunnel rests around the diverted bowel rather than perpendicular to it and should thereby help to avoid erosion. This also help to reduce prolapse formation as we know from the prophylactic use for PSH prevention [10]. During the procedure the mesh is already maneuvered into position by the bowel inside the funnel which further facilitates the orientation of the implant. A separation of the abdominal wall's layers with the associated risk of hemorrhage or infection is not necessary. Local access at the ostomy site makes dissection and removal of the hernia sac for seroma prevention easier. The additional open suture repair of the fascia narrows the former PSH defect and also helps with the preparation of an improved 'landing zone' for the implant. In our experience, this combined method delivers good results and makes a relocation of the ostomy into an other position unnecessary.

Biological meshes are not in use at the participating departments due of financial considerations and because systematic reviews have concluded that synthetic and biological implants showed equal results in the treatment of PSHs [21]. Furthermore, no increased infection rates and no mesh-associated complications were found for preventive implantation of synthetic mesh during which the bowel is always opened [22]. In accordance with these published findings, we have not encountered any mesh infections after laparoscopic intraperitoneal mesh placement during this study despite the long follow-up period of up to 12 years (146 months).

Limitations of the study are the retrospective analysis and the heterogeneity of the patient groups. Strengths are the multicenter design, high number of patients involved and the long follow-up period. The long period of the study allows to demonstrate the evolution of PSH repair in our units over this time.

Overall laparoscopic sandwich technique and PSH repair with a 3D funnel mesh device delivered the most promising results for our patients during the trial period. The procedures have proven to be safe and efficient. While the sandwich technique usually involves a purely laparoscopic approach, the ostomy reposition through a 3D funnel mesh combines the advantages of good laparoscopic view with good open access to facilitate local adhesiolysis, resection of the hernia sac, reduction of its content, and resection of redundant bowel. The development of the laparoscopic sandwich technique and the mesh funnel technique seems to have great promise. The high mortality in the group of emergent repairs should give weight to a more liberal approach to elective repair.

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Compliance with ethical standards

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