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## Retrospective study

**Complications of newborn enterostomies**

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**Abstract****AIM**

To evaluate the occurrence and severity of enterostomy complications in newborns suffering from different intestinal disorders.

**METHODS**

A 10-year retrospective cohort study (2008-2017) investigated newborns that underwent enterostomy formation and reversal for different intestinal disorders. Only infants less than 28 d old at the time of enterostomy creation were included in the study (corrected age was applied in the cases of preterm neonates). The patients were divided into two groups according to their underlying diseases. Group 1 included infants suffering from necrotizing enterocolitis (NEC), whereas Group 2 included newborns diagnosed with intestinal disorders other than NEC, such as meconium obstruction, ano-rectal malformation, focal intestinal perforation, ileus, intestinal atresia and volvulus. The primary outcome measure was enterostomy-related morbidity. The data were analyzed statistically using Pearson's  $\chi^2$  test or Fisher's exact test for categorical variables and the Wilcoxon-Mann-Whitney  $U$ -Test for continuous variables.

**RESULTS**

In total, 76 infants met the inclusion criteria and were evaluated for enterostomy-related complications. Neither group showed significant differences regarding gender, gestational age, weight at birth or weight at enterostomy formation. Infants suffering from NEC (Group 1) were significantly older at enterostomy for-

mation than the neonates of Group 2 [median (range), 11 (2-75) d *vs* 4 (1-101) d,  $P = 0.004$ ]. Significantly more ileostomies were created in Group 1 [47 (92.2%) *vs* 16 (64.0%),  $P = 0.007$ ], whereas colostomies were performed significantly more often in Group 2 [2 (3.9%) *vs* 8 (32.0%),  $P = 0.002$ ]. The initiation of enteral nutrition after enterostomy was significantly later in Group 1 infants than in Group 2 infants [median (range), 5 (3-13) *vs* 3 (1-9),  $P < 0.001$ ]. The overall rate of one or more complications in patients of both groups after enterostomy formation was 80.3%, with rates of 86.3% in Group 1 and 68.0% in Group 2 ( $P = 0.073$ ). Most patients suffered from two complications (23.7%). Four or more complications occurred in 21.6% of the infants in Group 1 and in 12.0% of the infants in Group 2 ( $P = 0.365$ ). Following enterostomy closure, at least one complication was observed in 26.0% of the patients (30.6% in Group 1 and 16.7% in Group 2,  $P = 0.321$ ). The occurrence of complications was not significantly different between neonates with NEC and infants with other intestinal disorders. 48 (65.8%) patients required no treatment or only pharmacological treatment for the complications that occurred [Clavien-Dindo-Classification (CDC)  $< \text{III}$ ], while 25 (34.2%) required surgery to address the complications (CDC  $\geq \text{III}$ ). Early reversal of the enterostomy was performed significantly more often ( $P = 0.003$ ) and the time to full enteral nutrition after closure was significantly longer [median (range), 7 (3-87) d *vs* 12 (5-93) d,  $P = 0.006$ ] in infants with a CDC grading  $\geq \text{III}$  than in infants with a CDC grading  $< \text{III}$ .

### CONCLUSION

Complications occur in almost all infants with enterostomies. The majority of these complications are minor and do not require surgical treatment. There is a clear trend that neonates with NEC have a higher risk for developing complications than those without NEC.

**Key words:** Enterostomy closure; Enterostomy; Stoma; Necrotizing enterocolitis; Neonates; Complications; Enterostomy formation

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**Core tip:** Infants with intestinal disorders often require surgical treatment consisting of enterostomy creation. However, enterostomy formation as well as its reversal frequently seems to lead to complications. The aim of this study was to assess the frequency, severity and impact of enterostomy complications in infants. In our study population, 80.3% of the infants presented with at least one complication following enterostomy formation, and 26.0% presented with complications after enterostomy closure. In the majority of patients, there was no requirement for surgical intervention regarding those complications. Infants suffering from necrotizing enterocolitis have a higher risk for developing enterostomy complications than neonates suffering from other intestinal disorders.

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## INTRODUCTION

Enterostomy formation is performed in a variety of different intestinal conditions, such as necrotizing enterocolitis (NEC), meconium ileus (MI), anorectal malformation (ARM), focal intestinal perforation (FIP), intestinal atresia and volvulus. A debate on whether enterostomy formation should be the standard treatment for infants with acute abdominal surgical disease or whether primary anastomosis is more feasible in selected cases is ongoing<sup>[1-4]</sup>. Enterostomy is considered an appropriate option for children with NEC when surgical treatment is needed<sup>[5-9]</sup>. However, the formation and closure of enterostomies is associated with a notable morbidity<sup>[4,6,10-16]</sup>. Reported complication rates are as high as 68% in neonates with necrotizing enterocolitis<sup>[6]</sup>. Gastrointestinal disorders other than NEC may also make enterostomy formation necessary. Here, the related complications are observed just as often<sup>[12-15]</sup>. The frequent complications associated with enterostomy formation are prolapse, retraction, stenosis or necrosis of the stoma, parastomal hernia and breakdown of the skin<sup>[11-13,15]</sup>. After enterostomy closure, complications such as anastomotic leakage and bowel obstruction might occur<sup>[12-14,17]</sup>. Enterostomy can further prolong the need for parenteral nutrition, and in cases of high-output enterostomies, can make sufficient growth of the neonate more difficult<sup>[12,13,18]</sup>. Because the observed complications seem to vary in severity, a differentiated consideration of enterostomy formation is necessary. The question arises as to when and for whom enterostomy formation should be deemed the right treatment. Whether neonates with NEC, a life threatening disease with mortality rates ranging up to 30%<sup>[6,19,20]</sup>, have a higher risk for developing enterostomy-related complications than children with other intestinal disorders must be examined. In this study, we investigated the occurrence and severity of complications after enterostomy formation and its reversal.

## MATERIALS AND METHODS

### Patients

We performed a retrospective study of all infants who underwent enterostomy formation and reversal between the years 2008 to 2017 at our institution. Only infants under the age of 28 d at the time of enterostomy formation were included in the study (corrected age was applied for premature newborns). Information regarding demographic data, diagnosis, comorbidities, stoma localization, nutrition, complications after formation

**Table 1 Primary disease**

		<i>n</i> (%)
Group 1	NEC	51 (67.1)
Group 2	Other gastrointestinal disorders	25 (32.9)
	MI with CF	8 (10.5)
	MI without CF	2 (2.6)
	ARM	7 (9.2)
	FIP	3 (3.9)
	Ileus of unknown origin	2 (2.6)
	Intestinal atresia	2 (2.6)
	Volvulus	1 (1.3)

NEC: Necrotizing enterocolitis; MI: Meconium ileus; CF: Cystic fibrosis.

and reversal as well as reoperations was evaluated. The study population was additionally divided into two groups. The categorization of the neonates was made according to the underlying disease. Group 1 included all the infants suffering from NEC, whereas Group 2 included all newborns with other intestinal diseases (meconium ileus, anorectal malformation, focal intestinal perforation, ileus, intestinal atresia and volvulus). To examine the severity of the occurring complications, we applied the Clavien-Dindo-Classification, which allows the ranking of surgical complications. The primary outcome measure was enterostomy-related morbidity. Formation and closure were examined separately for complications of the stoma and the need for reoperation. All patients were operated on by senior pediatric surgeons (co-authors) using a standardized surgical technique.

This study was reviewed and approved by the Ethics Committee of the University Hospital Frankfurt (310/17).

### Statistical analysis

All statistical analyses were performed using BiAS 11.09 (Frankfurt, Germany) software. Continuous variables are described with median values and ranges. Categorical variables are presented as frequency and percentages. Pearson's  $\chi^2$  test or Fisher's exact test was applied for comparisons of categorical variables, and the Wilcoxon-Mann-Whitney *U*-Test was applied for analyses of continuous data. Only *P*-values < 0.05 were considered statistically significant.

## RESULTS

### Study population

A total of 82 patients were eligible for the study, but 6 patients had to be excluded due to having incomplete charts or transfer to another hospital and being lost for follow-up. Therefore, 76 patients were included in the study population (Table 1). Of these patients, 51 (67.1%) suffered from NEC (Group 1). The remaining 25 patients (32.9%) were diagnosed and treated for other intestinal disorders (Group 2). Here, 8 infants suffered from meconium ileus as a result of cystic fibrosis (CF), and 2 suffered from meconium ileus without CF. Furthermore, 7 newborns were diagnosed

with ARM, 3 were diagnosed with FIP, 2 were diagnosed with ileus of unknown origin and 2 were diagnosed with intestinal atresia. One patient suffered from volvulus. In the overall population, the median gestational age was 27 (range, 22-41) wk (Table 2). In total, 86.8% of the infants were born prematurely. The median infant weight at birth was 840 (range, 430-3400) g. At enterostomy formation, the median age was 9.5 (range, 1-101) d, and the median weight was 1025 (range, 450-3780) g. Comparing the populations of Group 1 and Group 2, there were no significant differences in gender, gestational age, birth weight or number of preterm infants (Table 2). Most of the infant comorbidities also did not significantly differ between the two groups. Only the number of congenital malformations was significantly higher (*P* = 0.002) in Group 2. Regarding enterostomy formation, there was no significant difference in weight, with medians of 1010 (range, 450-3780) g in Group 1 and 1310 (range, 480-3360) g in Group 2 (*P* = 0.373), but the age at formation was significantly lower in Group 2 (*P* = 0.004). The median here was 11 (range, 2-75) d in Group 1 compared to 4 (range, 1-101) d in Group 2. Overall, 3 (3.9%) patients died in the time after enterostomy formation. Two infants suffering from NEC died of cardiopulmonary failure due to severe sepsis, and one patient with intestinal atresia suffered from cardiovascular failure as part of a severe septic shock with polyserositis and multiple organ failure. The number of deceased patients did not significantly differ between the two groups. These patients were excluded from the subsequent evaluation.

### Enterostomy formation

There were 3 (3.9%) jejunostomies, 63 (82.9%) ileostomies and 10 (13.2%) colostomies performed (Table 3). The number of ileostomy formations was significantly higher (*P* = 0.007) in children diagnosed with NEC than in infants suffering from other intestinal diseases. Colostomies were created significantly (*P* = 0.002) more often in neonates of Group 2.

There was no difference in the duration of the stoma between groups, with a median of 12.5 (range, 0-90) wk in the overall population. After enterostomy formation, the initiation of enteral nutrition was possible after a median of 4 (range, 1-13) d concerning the overall population. Enteral nutrition began significantly (*P* < 0.001) earlier in Group 2 than in Group 1, with medians of 3 (range, 1-9) d and 5 (range, 3-13) d until onset, respectively. In total, 21.1% (15/71) of the infants required parenteral nutrition (PN) until closure, and 78.9% (56/71) were on full enteral nutrition prior to reversal with a median of 24.5 (range, 6-209) d until the end of PN. The three deceased patients as well as two neonates with incomplete case files regarding nutrition were excluded from this evaluation. Stool *via* enterostomy was noted at a median of 4 (range, 2-27) d after formation. No significant differences in

**Table 2 Comparison of group populations *n* (%)**

	Overall population	Group 1	Group 2	<i>P</i> -value
<i>n</i> (%)	76 (100)	51 (67.1)	25 (32.9)	
Female	42 (55.3)	29 (56.9)	13 (52.0)	0.877
Gestational age (wk)	27 (22-41)	27 (23-38)	28 (22-41)	0.637
Preterm infants	66 (86.8)	46 (90.2)	20 (80.0)	0.282
Weight at birth (g)	840 (430-3400)	850 (490-3370)	825 (430-3400)	0.709
Deceased patients	3 (3.9)	2 (3.9)	1 (4.0)	1
Comorbidities				
Cardiovascular system insufficiency	23 (30.3)	19 (37.3)	4 (16.0)	0.103
Bronchopulmonary dysplasia	17 (22.4)	13 (25.5)	4 (16.0)	0.522
Respiratory insufficiency	54 (71.1)	39 (76.5)	15 (60.0)	0.223
Recurrent sepsis	13 (17.1)	8 (15.7)	5 (20.0)	0.885
Septic shock	9 (11.8)	8 (15.7)	1 (4.0)	0.257
Congenital malformations	12 (15.8)	3 (5.9)	9 (36.0)	0.002
Age at enterostomy formation (d)	9.5 (1-101)	11 (2-75)	4 (1-101)	0.004
Weight at enterostomy formation (g)	1025 (450-3780)	1010 (450-3780)	1310 (480-3360)	0.373

**Table 3 Enterostomy formation *n* (%)**

	Overall population	Group 1	Group 2	<i>P</i> -value
<i>Enterostomy location</i>				
Jejunostomy	3 (3.9)	2 (3.9)	1 (4.0)	1
Ileostomy	63 (82.9)	47 (92.2)	16 (64.0)	0.007
Colostomy	10 (13.2)	2 (3.9)	8 (32.0)	0.002
Stoma duration (wk)	12.5 (0-90)	12 (0-35)	14 (1-90)	0.468
Days until initiation of enteral nutrition	4 (1-13)	5 (3-13)	3 (1-9)	< 0.001
Requiring PN until closure	15 (21.1)	9 (18.8)	6 (26.1)	0.541
Full enteral nutrition prior to reversal	56 (78.9)	39 (81.3)	17 (73.9)	0.541
Days until full enteral nutrition	24.5 (6-209)	22 (6-87)	29 (8-209)	0.288
Days until stool <i>via</i> enterostomy	4 (2-27)	4 (2-14)	5 (2-27)	0.918

PN: Parenteral nutrition.

the requirement for PN, the time to full enteral nutrition or the days until stool *via* enterostomy were observed between Groups 1 and 2.

**Complications of enterostomy formation**

Out of the 76 patients forming the study population, 62 suffered from at least one stoma complication (Table 4), resulting in a complication rate of 80.3% concerning creation of the enterostomy. In all, 44 neonates (86.3%) in Group 1 and 17 neonates (68.0%) in Group 2 had at least one enterostomy-related complication. The difference in the rate of complications between children with NEC and those with other intestinal disorders did not reach statistical significance (*P* = 0.073). The most common complication in both groups was skin excoriation, with 37 patients (48.7%) in the overall population being affected. Wound bleeding (30 cases, 39.5%) and prolapse (29 cases, 38.2%) occurred second most often. The days to onset of these complications are displayed in Table 5. The three most common complications did occur earlier in children suffering from NEC, but this observation was not significant (*P* = 0.098; *P* = 0.790; *P* = 0.901). Additionally, the following complications were observed: blistering of the skin (1), wound discharge (15), wound dehiscence (1), insufficient circulation of enterostomy

(17), enterostomy necrosis (4), mechanical ileus (8), prestomal stenosis (10), parastomal hernia (1) and perforation (1). Finally, there was one case of abdominal compartment syndrome following formation surgery. Comparing Groups 1 and 2, no significant differences in the occurrence of enterostomy-related complications were observed. In total, 15 infants (19.7%) did not present any complications after enterostomy formation (Table 6), including 7 neonates (13.7%) in Group 1 and 8 neonates (32.0%) in Group 2 (*P* = 0.073). 21.1% of the newborns suffered from one complication. However, in most children, a total of two complications occurred (23.7%). Furthermore, 17.1% of the neonates suffered from three complications, while 13.2% suffered from four complications, and 3.9% suffered from five complications. A maximum of 7 complications occurred in one patient (1 case = 1.3%). Of the neonates in Group 1, 21.6% suffered from 4 or more complications, as opposed to 12.0% of the infants in Group 2 suffering from at least 4 complications (*P* = 0.365). Furthermore, 16 patients (21.9%) failed to thrive under enterostomy, including 10 in Group 1 (20.4%) and 6 (25%) in Group 2 (Table 4). At least one reoperation was necessary in 9 patients (11.8%), with mechanical ileus being the main indication for reoperation (Table 4). No significant difference regarding reoperation was found between

**Table 4 Complications of enterostomy formation *n* (%)**

	Overall population	Group 1	Group 2	P-value
Patients with ≥ 1 complication	62 (80.3)	44 (86.3)	17 (68.0)	0.073
Complications	152	110	42	
Skin excoriation	37 (48.7)	27 (52.9)	10 (40.0)	0.414
Blister	1 (1.3)	1 (2.0)	0 (0.0)	1
Wound discharge	15 (19.7)	12 (23.5)	3 (12.0)	0.359
Wound bleeding	30 (39.5)	21 (41.2)	9 (36.0)	0.854
Prolapse	29 (38.2)	22 (43.1)	7 (28.0)	0.305
Wound dehiscence	1 (1.3)	0 (0.0)	1 (4.0)	0.329
Insufficient circulation of enterostomy	17 (22.4)	10 (19.6)	7 (28.0)	0.595
Necrosis of enterostomy	4 (5.3)	4 (7.8)	0 (0.0)	0.296
Mechanical ileus	8 (10.5)	4 (7.8)	4 (16.0)	0.388
Parastomal hernia	1 (1.3)	1 (2.0)	0 (0.0)	1
Prestomal obstruction/stenosis	10 (13.2)	8 (15.7)	2 (8.0)	0.482
Perforation	1 (1.3)	1 (2.0)	0 (0.0)	1
Abdominal compartment syndrome	1 (1.3)	1 (2.0)	0 (0.0)	1
Failure to thrive under enterostomy	16 (21.9)	10 (20.4)	6 (25.0)	0.885
Patients with ≥ 1 reoperation	9 (11.8)	6 (11.8)	3 (12.0)	1
Mechanical ileus	7 (9.2)	3 (5.9)	4 (16.0)	0.069
Insufficient improvement of health	3 (3.9)	3 (5.9)	0 (0.0)	0.505
Abdominal compartment syndrome	1 (1.3)	1 (2.0)	0 (0.0)	1
Intestinal perforation	2 (2.6)	2 (3.9)	0 (0.0)	1
Colon necrosis	1 (1.3)	1 (2.0)	0 (0.0)	1

**Table 5 Onset of most common enterostomy complications**

	Overall population	Group 1	Group 2	P-value
Skin excoriation	27 (6-143)	26 (6-103)	31.5 (10-143)	0.098
Wound bleeding	12.5 (2-128)	11 (2-128)	14 (2-71)	0.79
Prolapse	57 (5-165)	60.5 (5-165)	52 (5-119)	0.901

**Table 6 Number of enterostomy formation-related complications in one patient *n* (%)**

	Overall population	Group 1	Group 2	P-value
None	15 (19.7)	7 (13.7)	8 (32.0)	0.073
1	16 (21.1)	12 (23.5)	4 (16.0)	0.648
2	18 (23.7)	13 (25.5)	5 (20.0)	0.809
3	13 (17.1)	8 (15.7)	5 (20.0)	0.748
4	10 (13.2)	8 (15.7)	2 (8.0)	0.482
5	3 (3.9)	2 (3.9)	1 (4.0)	1
6	0 (0.0)	0 (0.0)	0 (0.0)	
7	1 (1.3)	1 (2.0)	0 (0.0)	1
≥ 4	14 (18.4)	11 (21.6)	3 (12.0)	0.365

the two population groups.

As all newborns were operated on by senior surgeons, there were no differences in experience regarding the treatment. No correlation of enterostomy related complications to the surgeon's experience could therefore be observed.

### Enterostomy closure

In 28 patients (38.4%), an early reversal of the enterostomy was required (Table 7). The most common indication was failure to thrive under enterostomy (12). Furthermore, prolapse (7), stenosis (5), necrosis of enterostomy (1) and parastomal hernia (1) led to early stoma reversal. There were no significant differences

regarding early closure between the children of Group 1 and those of Group 2. The start of enteral nutrition was achieved at a median of 2 (range, 1-18) days after enterostomy closure, and full enteral nutrition was possible at a median of 8 (range, 3-39) d. After a median of 3 (range, 1-13) d, rectal stool could be observed. These data did not vary significantly between infants suffering from NEC (Group 1) and those diagnosed with other intestinal disorders (Group 2).

### Complications of enterostomy closure

In the overall population, the complication rate after closure was 26% (Table 8). In total, 15 neonates (30.6%) in Group 1 and 4 neonates (16.7%) in Group 2 suffered from at least one complication following reversal ( $P = 0.321$ ). The complication that was seen most often after reversal was mechanical ileus, affecting 8 subjects (11%) in the overall population. Furthermore, cases of general postoperative infection (4), wound infection (3), subcutaneous hematoma (1) and seroma of the laparotomy wound (1) were observed in infants of Group 1. Anastomotic leakage occurred in 2 patients and affected only neonates suffering from NEC (Group 1). One patient suffered a wound dehiscence with intestinal prolapse after surgery for enterostomy closure. There was no significance between the occurrence of a complication after reversal and the group of the affected newborn. At least one

**Table 7 Enterostomy closure *n* (%)**

	Overall population	Group 1	Group 2	<i>P</i> -value
Early reversal necessary	28 (38.4)	19 (38.8)	9 (37.5)	1
Failure to thrive under enterostomy	12 (16.4)	7 (14.3)	5 (20.8)	0.432
Prolapse	7 (9.6)	4 (8.2)	3 (12.5)	0.646
Stenosis of enterostomy	4 (5.5)	3 (6.1)	1 (4.2)	1
Necrosis of enterostomy	1 (1.4)	1 (2.0)	0 (0.0)	1
Parastomal hernia	1 (1.4)	1 (2.0)	0 (0.0)	1
As part of a not enterostomy-related surgery	3 (4.1)	3 (6.1)	0 (0.0)	0.53
Days until initiation of enteral nutrition	2 (1-18)	2 (1-18)	2 (1-6)	0.151
Days until full enteral nutrition	8 (3-93)	8 (3-93)	7 (4-41)	0.966
Days to rectal stool	3 (1-13)	3 (1-12)	3 (2-13)	0.732

**Table 8 Complications of enterostomy closure *n* (%)**

	Overall population	Group 1	Group 2	<i>P</i> -value
Patients with ≥ 1 complication	19 (26.0)	15 (30.6)	4 (16.7)	0.321
Mechanical ileus	8 (11.0)	4 (8.2)	4 (16.2)	0.426
Subcutaneous hematoma	1 (1.4)	1 (2.0)	0 (0.0)	1
Wound dehiscence with intestinal prolapse	1 (1.4)	0 (0.0)	1 (4.2)	0.329
Wound infection	3 (4.1)	3 (6.1)	0 (0.0)	0.546
Postoperative infection	4 (5.5)	4 (8.2)	0 (0.0)	0.299
Seroma of laparotomy wound	1 (1.4)	1 (2.0)	0 (0.0)	1
Anastomotic leakage	2 (2.7)	2 (4.1)	0 (0.0)	1
Patients with ≥ 1 reoperation	10 (13.7)	6 (12.2)	4 (16.7)	0.72
Mechanical ileus	8 (11.0)	4 (8.2)	4 (16.7)	1
Wound dehiscence with intestinal prolapse	1 (1.4)	0 (0.0)	1 (4.2)	0.455
Anastomotic leakage	2 (2.7)	2 (4.1)	0 (0.0)	0.455

**Table 9 Clavien-Dindo-Classification *n* (%)**

	Overall population	Group 1	Group 2	<i>P</i> -value
I	31 (42.5)	23 (46.9)	8 (33.3)	0.399
II	6 (8.2)	6 (12.2)	0 (0.0)	0.169
IIIa	0 (0.0)	0 (0.0)	0 (0.0)	
IIIb	14 (19.2)	9 (18.4)	5 (20.8)	1
IVa	11 (15.1)	6 (12.2)	5 (20.8)	0.489
IVb	0 (0.0)	0 (0.0)	0 (0.0)	
V	0 (0.0)	0 (0.0)	0 (0.0)	

reoperation after closure was necessary in 10 (13.7%) patients, with mechanical ileus being the most common indication. Between Groups 1 and 2, the rates and causes of reoperation did not differ significantly.

**Clavien-Dindo-classification**

In applying the Clavien-Dindo-Classification (CDC) for surgical complications, a total of 31 (42.5%) patients were identified as Grade I (Table 9). A grade of I indicated that the surgical complication was minor, and no pharmacological or surgical intervention was therefore necessary. Treatment with pharmacological agents, such as antibiotics (CDC Grade II), was needed in 6 (8.2%) cases. Grade III can be divided into IIIa (surgical intervention under local anesthesia) and IIIb (surgical intervention under general anesthesia). No children were classified as IIIa, but 14 children (19.2%) were classified as IIIb. In all, 11 (15.1%) infants suffered from a life-threatening complication of one organ

(CDC Grade IVa). None of the children were classified as grade IVb (life-threatening complication concerning multiple organ systems) or Grade V (death). There were no significant differences between the underlying diseases of the neonates (group) and their CDC grade. In all, 48 (65.8%) infants had a CDC grading < III, and 25 (34.2%) had a grading ≥ III (Table 10). Comparing neonates with a CDC grade < III who did not require surgical treatment to infants with a CDC grade ≥ III who did, infants with a CDC grade ≥ III required early reversal of the enterostomy significantly more often (25.0% vs 64.0%; *P* = 0.003). Furthermore, children with a high CDC grade (≥ III) required a significantly longer amount of time to reach full enteral feeding than those with a grade < III, with medians of 12 (range, 5-93) d and 7 (range, 3-87) d, respectively (*P* = 0.006). None of the other data showed significant differences in regard to CDC grading.

**Effect of complications on the clinical course**

To assess any relationship between a specific complication and its consequences on the affected neonate, we further examined the complications in regard to the reoperation rate, CDC grading and need for early reversal (Table 11). The occurrence of a mechanical ileus following enterostomy formation showed a significant correlation with the need for reoperation and a higher CDC grade (*P* ≤ 0.001; *P* = 0.001). Prestomal obstruction of the intestines was also significantly associated with a CDC grade ≥ III (*P* = 0.028).

**Table 10** Associations with the occurrence of severe enterostomy-related complications

	CDC < III	CDC ≥ III	P-value
n (%)	48 (65.8)	25 (34.2)	
Gestational age (wk)	27 (23-38)	26 (22-41)	0.931
Birth weight (g)	867.5 (430-3370)	812 (460-3400)	0.591
Preterm infants	43 (89.6)	21 (84.0)	0.481
Age at enterostomy formation	9 (1-75)	16 (1-101)	0.159
Weight at enterostomy formation	1005 (480-3780)	1600 (450-3360)	0.699
Days until initiation of enteral nutrition after formation	4 (1-13)	4 (1-9)	0.29
Patients requiring PN until reversal	7 (14.6)	8 (32.0)	0.135
Days until full enteral nutrition after formation	24.5 (6-87)	25 (10-209)	0.634
Days until stool via enterostomy (wk)	4 (2-12)	5 (2-27)	0.487
Duration of enterostomy (wk)	13 (0-90)	12 (0-58)	0.682
Early reversal necessary	12 (25.0)	16 (64.0)	0.003
Days until initiation of enteral nutrition after reversal	2 (1-8)	2 (1-18)	0.389
Days until full enteral nutrition after reversal	7 (3-87)	12 (5-93)	0.006
Days to rectal stool	3 (1-12)	4 (1-13)	0.645

PN: Parenteral nutrition; CDC: Clavien-Dindo-Classification.

**Table 11** Effect of complications on clinical course

	Reoperation	CDC ≥ III	Early reversal
<b>Formation</b>			
Skin excoriation	0.736	1	0.882
Blister	0.12	0.342	1
Wound discharge	1	1	1
Wound bleeding	1	0.759	0.498
Prolapse	1	0.774	1
Wound dehiscence	1	1	1
Insufficient circulation of enterostomy	0.205	0.99	0.577
Necrosis of enterostomy	0.068	0.269	0.052
Mechanical ileus	< 0.001	0.001	1
Parastomal hernia	0.12	0.342	0.384
Obstruction/stenosis	0.094	0.026	0.492
Perforation	0.12	1	1
Abdominal compartment syndrome	0.12	0.342	0.384
Failure to thrive under enterostomy	0.676	0.99	< 0.001
<b>Reversal</b>			
Mechanical ileus	< 0.001	< 0.001	
Subcutaneous hematoma	1	1	
Wound dehiscence with intestinal prolapse	0.137	0.342	
Wound infection	0.362	0.269	
Postoperative infection	1	1	
Seroma of laparotomy wound	1	1	
Anastomotic leakage	0.014	0.108	

CDC: Clavien-Dindo-Classification.

Furthermore, infants suffering from failure to thrive under enterostomy underwent early reversal significantly more often than those who did not ( $P < 0.001$ ). None of the other complications occurring after formation showed a significant association with reoperation, a CDC grade  $\geq$  III or early reversal. Among the complications related to enterostomy closure, patients with a mechanical ileus were significantly more likely to undergo reoperation ( $P < 0.001$ ) and receive a higher CDC grade than those without a mechanical ileus ( $P = 0.002$ ). Finally, anastomotic leakage showed a significant correlation with reoperation ( $P = 0.014$ ). None of the other closure-related complications had any significant impact on the clinical course of the affected infant.

## DISCUSSION

The purpose of this retrospective study was to evaluate the occurrence of enterostomy-related complications in neonates suffering from different intestinal disorders. We investigated the frequency and severity of complications after formation as well as after closure. Furthermore, the possible impacts of complications on the clinical course of the affected infants were evaluated. After enterostomy formation, a complication rate as high as 80.3% was observed in the overall study population, with a total of 62 infants suffering from at least one enterostomy related complication. In most cases, more than one complication occurred, and

sometimes, even three, four or five complications were observed in one patient. Previous studies also found enterostomy complications after formation to be fairly frequent, with reported rates varying between 34% and 66%<sup>[4,12,13,15-17]</sup>. The number of complications present in one infant is rarely reported<sup>[6]</sup>. If mentioned, the rates varied between 1 and a maximum of 4 complications per patient<sup>[12,13]</sup>. In our study, the most common complication after formation was skin excoriation, which occurred in almost half of all the neonates. Other authors either did not include skin excoriation in their evaluation of complications or observed lower rates<sup>[11,13,15,17]</sup>. Why our complication rates after formation were higher than those described by other authors might be explained by the inclusion of complications, such as skin excoriation and insufficient circulation of the enterostomy. These rather minor events might often be overlooked in a case record review, but because they affect so many infants, we found it essential to not dismiss them. Regarding closure of the enterostomy, there is an ongoing debate on whether early or late reversal lead to more complications. A number of authors have explored this question of optimal timing for enterostomy closure, but there is still no consensus regarding the topic<sup>[12-14,21-24]</sup>. In our study, stoma closure was performed at a median of 12.5 weeks and 26.0% of all infants suffered from a complication following the reversal. This result is comparable to findings of other studies reporting rates between 10% and 32.6%<sup>[1,13,14,17]</sup>. Only Lee *et al.*<sup>[12]</sup> reported a complication rate as high as 64.8% after enterostomy closure.

The severity of those enterostomy-related complications has not been evaluated in detail. Therefore, we applied the Clavien-Dindo-Classification grading system. By means of this classification, we discovered that most enterostomy-related complications were indeed minor, with 42.5% of the patients with complications not requiring any treatment (CDC Grade I) or only pharmacological intervention (8.2% with CDC Grade II). This classification system also revealed that in 34.2% of all neonates, a surgical procedure was required to address the sometimes life-threatening complications (CDC  $\geq$  III). Neonates with a CDC grade  $\geq$  III needed to undergo early reversal significantly more often and took a significantly longer amount of time to reach full enteral nutrition, demonstrating that infants are certainly impacted by more severe complications concerning their clinical course.

The complication leading to reoperation most often was a mechanical ileus. A significant association with a CDC grade  $\geq$  III was furthermore observed. However, this complication must be evaluated fairly critically, as it is not entirely clear whether its occurrence can be traced back to the enterostomy formation itself or is rather a result of the primary disease and previous surgical procedures. Apart from that, anastomotic leakage also showed a significant association with reoperation. Prestomal obstruction had a significant relationship with CDC grades  $\geq$  III. All the other enterostomy-related

complications, ranging from skin excoriation to necrosis and parastomal hernia, had no significant effects on the clinical course of the neonates. Interestingly, the occurrence of enterostomy prolapse, a very common complication<sup>[6,10-12,15,17]</sup>, did not show a significant correlation with reoperation, the CDC grade, or early reversal. Therefore, even though stoma prolapse can sometimes make early reversal necessary (7 cases in our study), most infants are able to thrive despite it, and neither reoperation nor reversal is necessary.

Overall, one could argue that stomal complications are very common and only of benign nature in most cases. However, if more major complications arise, they may affect the neonate regarding nutrition and the need for reoperation or early reversal.

Additionally, our aim was to determine whether enterostomy formation should be the standard for all infants with intestinal diseases or whether, in some cases, an alternative treatment should be explored first to avoid possible complications. Thus far, enterostomy formation has not been proven to be the best option for neonates with intestinal diseases. Hall *et al.*<sup>[1]</sup> showed that primary anastomosis is also a valid option for children with NEC, as they reported that no occurrences of anastomotic leakage or strictures were observed following the procedure. Harberg *et al.*<sup>[2]</sup> also found primary anastomosis to be suitable for most cases and Hofman *et al.*<sup>[3]</sup> even argued that primary anastomosis might be superior to enterostomy after resection, as those children had a significantly shorter hospital stay. Furthermore Griffiths *et al.*<sup>[4]</sup> found the complication rate after anastomosis to be much lower than after enterostomy formation (60% vs 17%, respectively).

To determine whether primary disease has any effect on enterostomy-related complications, we categorized our study population according to their diagnosis. The two groups (NEC vs other intestinal disorders) had similar starting points and did not differ significantly in gender, gestational age, weight at birth, most comorbidities or weight at enterostomy formation. There were only two significant differences. First, there was a higher number of neonates with congenital malformations in Group 2, which can be easily traced back to the number of infants suffering from ARM in the second group. Second, enterostomy was created later than in newborns with NEC than in those of the other cohort. This delay can be explained by the nature of some intestinal diseases, such as ARM and intestinal atresia, being congenital and requiring urgent treatment right after birth, whereas the median age of necrotizing enterocolitis onset is reported to be 12 d, thereby allowing surgical treatment to come into play later<sup>[25]</sup>.

The fact that the two cohorts were very similar allowed us to evaluate the occurrence of complications without considering other factors, such as gestational age, birth weight, and weight and age at enterostomy formation. In particular, a number of studies have already examined the impacts of those parameters and reported significant associations of low birth weight,

young gestational age, low weight at enterostomy formation and closure with the occurrence of complications<sup>[6,11,12]</sup>. The similarity of the cohorts enabled us to focus mainly on the relationship between the primary disease and complication development. Thus far, authors have only reported that no correlation exists between primary disease and enterostomy complications<sup>[13,15,17]</sup>. However, as infants diagnosed with NEC suffer from a systemic disease in which their intestines are generally inflamed and vulnerable, we herein suspected that those undergoing enterostomy would be more prone to complications. In infants with other intestinal diseases, such as atresia, ileus, volvulus and ARM, the overall state of their intestines and their integrity is not as compromised simply due to the physiological backgrounds of these conditions.

Even though we could not show a statistically significant relationship between the occurrence of enterostomy complications and the underlying pathology, we did identify a trend in the evaluated data. Some results could in fact indicate that neonates suffering from NEC are slightly more at risk for developing enterostomy-related complications. We made this assumption due to several findings. First of all, the complication rate following formation was higher in newborns with NEC than in infants with other intestinal diseases (86.3% vs 68.0%, respectively), although this difference was not statistically significant ( $P = 0.073$ ). The onsets of the three most common complications, skin excoriation ( $P = 0.098$ ), wound bleeding ( $P = 0.790$ ) and prolapse ( $P = 0.901$ ), were observed earlier in neonates with NEC, which again supports our hypothesis that the intestines of these infants were simply more susceptible to irritations. Additionally, neonates of Group 1 frequently suffered from four or more complications (21.6%), whereas most infants in Group 2 suffered from only two or three enterostomy-related complications and rarely suffered from four or more (12.0%) ( $P = 0.365$ ). Group 2, however, had a higher rate of newborns with no occurrence of stomal complications after formation (32.0% vs 13.7% in Group 1;  $P = 0.073$ ). Finally, more neonates had complications after enterostomy closure in Group 1 (30.6%) than in Group 2 (16.7%) ( $P = 0.321$ ). Together, these findings do suggest that because their bowel integrity is very low, infants with NEC are just slightly more prone to enterostomy-related complications than those without NEC.

In conclusion, enterostomy treatment is associated with a high frequency of minor complications and only a few major complications. The major complications do have an impact on the infant's clinical course and lead to prolonged parenteral nutrition or a need for reoperation and early reversal. However, in the majority of cases, infants do not need to undergo surgical treatment to address the enterostomy-related complications. Neonates suffering from NEC have a higher risk for developing enterostomy complications than those without NEC.

## ARTICLE HIGHLIGHTS

### Research background

Infants with intestinal disorders often require surgical treatment consisting of enterostomy creation. However, enterostomy formation as well as its reversal frequently seem to lead to complications. Past studies have reported complication rates as high as 68% following enterostomy formation. Reported rates after enterostomy reversal are similarly high with up to 64.8% of neonates affected. Possible complications of the enterostomy range from skin excoriation and prolapse to enterostomy necrosis or mechanical ileus.

### Research motivation

In some cases of patients with enterostomy-related complications further medical treatment or even reoperations can be necessary. Furthermore the nutrition and therefore growth of the infant can be impacted by occurring complications. This poses the question whether enterostomy formation is an appropriate surgical treatment for newborns with intestinal disorders. It also has to be evaluated for whom enterostomy formation should be deemed the right treatment.

### Research objectives

The aim of this study was to assess the frequency, severity and impact of enterostomy complications in infants. We furthermore wanted to examine whether neonates with necrotizing enterocolitis (NEC), a life threatening disease with mortality rates ranging up to 30%, have a higher risk for developing enterostomy-related complications than children with other intestinal disorders.

### Research methods

A 10-year retrospective cohort study (2008-2017) investigated newborns who underwent enterostomy formation and reversal for different intestinal disorders. Only infants less than 28 d old at the time of enterostomy creation were included in the study (corrected age was applied in the cases of preterm neonates). The patients were divided into two groups according to their underlying diseases. Group 1 included infants suffering from NEC, whereas Group 2 included newborns diagnosed with intestinal disorders other than NEC, such as meconium obstruction, anorectal malformation, focal intestinal perforation, ileus, intestinal atresia and volvulus. The primary outcome measure was enterostomy-related morbidity. The data were analyzed statistically and to evaluate the severity of the occurring complications, the Clavien-Dindo-Classification was applied, which allows the ranking of surgical complications.

### Research results

In total, 76 infants met the inclusion criteria and were evaluated for enterostomy-related complications. Neither group showed significant differences regarding gender, gestational age, weight at birth or weight at enterostomy formation. The overall rate of one or more complications in patients of both groups after enterostomy formation was 80.3%, with rates of 86.3% in Group 1 and 68.0% in Group 2 ( $P = 0.073$ ). Following enterostomy closure, at least one complication was observed in 26.0% of the patients (30.6% in Group 1 and 16.7% in Group 2,  $P = 0.321$ ). 65.8% of patients required no treatment or only pharmacological treatment for the complications that occurred (Clavien-Dindo-Classification < III), while 34.2% required surgery to address the complications (CDC  $\geq$  III). Early reversal of the enterostomy was performed significantly more often ( $P = 0.003$ ) and the time to full enteral nutrition after closure was significantly longer ( $P = 0.006$ ) in infants with a CDC grading  $\geq$  III than in infants with a CDC grading < III.

### Research conclusion

Enterostomy treatment is associated with a high frequency of minor complications (CDC < III) and only a few major (CDC  $\geq$  III) complications. The major complications do have an impact on the infant's clinical course and lead to prolonged parenteral nutrition or a need for reoperation and early reversal. However, in the majority of cases, infants do not need to undergo surgical treatment to address the enterostomy-related complications. Regarding the underlying disease of the infants a clear trend could be observed that neonates suffering from NEC have a higher risk for developing enterostomy complications

than those without NEC. This may be explained by the fact that bowel integrity in those infants is typically very low.

### Research perspective

Enterostomy creation frequently leads to complications, but nevertheless can be deemed an appropriate surgical treatment for most infants suffering from intestinal disorders. It needs to be further evaluated though, whether an alternative treatment such as primary anastomosis might be a more feasible option in some cases. Especially the right treatment of children with NEC should be studied further in the future.

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