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ORIGINAL ARTICLE

Emergency repair of inguinal hernia in the premature infant is associated with high direct medical costs

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Abstract

Purpose Inguinal hernia repair is frequently performed in premature infants. Evidence on optimal management and timing of repair, as well as related medical costs is still lacking. The objective of this study was to determine the direct medical costs of inguinal hernia, distinguishing between premature infants who had to undergo an emergency procedure and those who underwent elective inguinal hernia repair.

Methods This cohort study based on medical records concerned premature infants with inguinal hernia who underwent surgical repair within 3 months after birth in a tertiary academic children's hospital between January 2010 and December 2013. Two groups were distinguished: patients with incarcerated inguinal hernia requiring emergency repair and patients who underwent elective repair. Real medical costs were calculated by multiplying the volumes of healthcare use with corresponding unit prices. Nonparametric bootstrap techniques were used to derive a 95 % confidence interval (CI) for the difference in mean costs.

Results A total of 132 premature infants were included in the analysis. Emergency surgery was performed in 29 %. Costs of hospitalization comprised 65 % of all costs. The total direct medical costs amounted to €7418 per premature infant in the emergency repair group versus €4693 in the elective repair group. Multivariate analysis showed a difference in costs of €1183 (95 % CI −1196; 3044) in favor of elective repair after correction for potential risk factors.

Conclusion Emergency repair of inguinal hernia in premature infants is more expensive than elective repair, even after correction for multiple confounders. This deserves to be taken into account in the debate on timing of inguinal hernia repair in premature infants.

Keywords Inguinal hernia · Premature infants · Cost analysis · Emergency repair

Introduction

Inguinal hernia repair is the most frequently performed procedure in pediatric surgery. The cumulative incidence of inguinal hernia is up to 9.0 % in prematurely born children. More than half these patients will undergo hernia repair in the first year of life [1, 2].

Eventually all premature infants with an inguinal hernia have to undergo surgical repair [3–5]. However, evidence on the optimal management and timing of inguinal hernia repair in these neonates is lacking. Delayed repair seems

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appealing as premature infants often have concomitant comorbidities and are vulnerable for perioperative complications [2]. On the other hand, delaying elective repair can be complicated by incarceration, in which case emergency surgery is needed. In a previous study we showed that more than 50 % of premature infants with an inguinal hernia present with a symptomatic inguinal hernia, and emergency repair was needed in more than half of these cases due to incarceration [6]. Emergency repair is associated with a higher risk of surgical and anesthetic complications and has been found to result in a longer duration of hospitalization, more readmissions, and even reoperations [2, 6].

To prevent possible emergency repair in premature infants, some surgeons prefer to perform surgery during the birth hospitalization, before discharge from the neonatal intensive care unit (NICU). Although this intervention prolongs initial hospitalization, it avoids readmission for elective repair [7]. Delayed elective repair may also result in repeated herniation and reduction at the emergency department (ED), multiple visits to the outpatient clinic (OPC), and perhaps a longer perioperative admission on the pediatric ward or NICU, which is likely to raise direct medical costs [8, 9].

The timing of surgery is mostly based on expert opinion and the surgeon's personal preference. In the current era of tightening budgets, economic aspects have captured the interest of healthcare policy makers [10, 11]. Except for a mid-1980s study that compared treatment costs in premature infants operated on prior to discharge from the NICU and in full-term infants operated on as outpatients, there are no data on costs of inguinal hernia repair in premature infants in relation to timing of repair [7]. Bearing in mind that surgery in premature patients is very costly, insight into the actual costs of different strategies in inguinal hernia repair would be relevant for planning and organization of care, for supporting clinical decisions, and for efficient allocation of health care resources.

The objective of this study was to compare the medical costs of inguinal hernia repair in premature infants between patients who had to undergo emergency repair and those who underwent elective repair.

Methods

Setting and patients

A cohort study on medical records was performed at a tertiary academic children's hospital in the Netherlands. All premature infants (defined as gestational age <37 weeks) who presented at the ED or at the OPC and operated on for inguinal hernia within 3 months after birth between January 2010 and December 2013 were included. They were identified from the electronic hospital data systems and medical charts using the so-called "Centraal Orgaan Tarieven Gezondheidszorg" (COTG) codes (unilateral inguinal hernia repair: CTG335700; bilateral inguinal hernia repair: CTG335701; incarcerated inguinal hernia repair without bowel resection: CTG335702; incarcerated inguinal hernia repair with bowel resection: CTG334639; recurrent inguinal hernia repair: CTG335710).

Study groups and patient exclusion criteria

Two groups of premature infants were distinguished: (1) those who underwent elective inguinal hernia repair and (2) those who had to undergo an emergency procedure because of incarceration of contents in the hernia sac. Emergency surgery was defined as inguinal hernia repair performed within 24 h after incarceration and not scheduled on the surgeon's elective procedure list. Patient characteristics and clinical data were collected from medical records and have been published already [6]. Premature infants who were initially admitted for conditions other than inguinal hernia, who were still hospitalized since birth, or who were admitted more than 72 h before surgery, were excluded because it was not possible to separate costs associated with inguinal hernia from costs associated with treatment for other conditions. All patients were operated on after discharge from their birth hospitalization; in all prematures general anesthesia were used, whether or not combined with a caudal block or loco-regional anesthesia. Premature born infants operated on with a gestational age of 40 weeks or younger, were postoperatively admitted to the NICU. Patients with a gestational age of 40–45 weeks had to stay in the recovery room for 2 h after which they were admitted to the ward. This institutional policy is based on national guidelines from the Dutch Society of Anaesthesia. Prolonged mechanical ventilation was only performed if clinically indicated, mostly due to pulmonary comorbidities.

Cost calculation

Direct medical costs were considered to be all costs within the hospital sector directly related to the studied treatment, including the hospital's outpatient setting. Per patient, we took into account (1) costs of hospitalization (NICU or high care or medium care unit, and readmissions); (2) costs of outpatient care (i.e., visits to OPC, visits to ED, and telephone consultations); (3) costs of diagnostic procedures and perioperative care (i.e., ultrasound and anaesthesiologist consultations); and (4) costs of surgical procedures (i.e., operating rooms (OR), OR during after hours,

Table 1 Cost categories and data used in cost calculation based on real costs

	Parameter	Cost price (€)
Hospitalization		
NICU	Day	1540
High care unit	Night	859
Normal care unit	Night	447
Outpatient clinic visits		
First visit to OPC	Visit	226
Follow-up at OPC	Visit	175
Emergency department	Visit	243
Telephonic consultation	Call	135
Perioperative consultation		
Ultrasound	Number	81
Preoperative consultation ANA	Visit	125
Surgical procedure		
Use of OR	/10 min	74
Use of OR afterhours	/10 min	223
Anesthetist's fee	/10 min	22
Surgeon's fee	/10 min	22
Anesthetist's fee afterhours	/10 min	22
Surgeon's fee afterhours	/10 min	22

All cost prices are based on real costs rather than charges. Costs in Euro for the first of January 2014, when 1 Euro (€) equalled approximately 1.38 US Dollar

NICU neonatal intensive care unit, *OPC* outpatient clinic, *ANA* anaesthesiology, *OR* operating room

Day, cost price calculated for each calendar day a patient is hospitalized; night, cost price calculated for every overnight stay per patient

reoperations and costs of anaesthesiologists and surgeons). Table 1 provides an overview of the cost categories and the unit prices used in the cost calculations.

Real medical costs were calculated by multiplying the volumes of healthcare use with the corresponding unit prices. Unit prices were determined with the micro-costing method, which implies a detailed inventory and measurement of all resources used [12, 13]. For hospital days, the cost price included costs for nursing staff, buildings, and equipment (specialists' fees not included). The unit price for the NICU was calculated for each calendar day an individual was hospitalized; the unit price for a stay on the medium- or high-care was calculated per overnight stay. Regarding the costs of the surgical procedure, the cost price included fees of the surgeons and anesthesiologists, costs of the OR, including costs of OR assistants, anesthesiology nurses, equipment, buildings, etc. For visits to the ED and OPC, preoperative consultation, and ultrasounds, the cost price included the fees of the surgeons, anesthesiologists, and radiologists. All admissions due to a reoperation or admissions that were inguinal hernia related, or related to the first admission, were interpret to be readmissions. We reported costs in Euro for the first of January 2014, when 1 Euro (€) equalled approximately 1.38 US Dollar.

Data analysis

SPSS 21.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Fisher exact tests and Mann–Whitney U tests were used to compare costs of emergency- and elective repair. Since cost data per patient are typically highly skewed, we used nonparametric simple bootstrap techniques with a 1000 samples. To derive a 95 % confidence interval for the differences in distributions of the direct medical costs, we used the percentile bootstrap method. We used a linear regression model to control for confounders. Potential risk factors with a p value <0.05 were included in the model (i.e., birth weight, age at repair, history of bradycardia, and mechanical ventilation). A p value of <0.05 was considered statistically significant.

Results

Between January 2010 and December 2013, 142 premature infants underwent inguinal repair within 3 months after birth. Ten patients were excluded because they were admitted more than 72 h before surgery. The mean gestational age at birth was 34 weeks (SD 17 days). Mean birth weight was 1916 g (SD 543 g), mean follow-up was 27 weeks (SD 15 weeks), and mean time from diagnosis to surgery was 13 days (SD 12 days).

Seventy-two of the 132 included infants (55 %) presented with a symptomatic inguinal hernia, of whom 38 (29 %) needed subsequent emergency repair due to incarceration within 24 h. In the other 34 infants (26 %), the symptomatic hernias could be reduced manually and delayed elective surgery was performed. Nine patients had no incarceration at first presentation, but returned to the ED with an incarcerated hernia and had to undergo emergency surgery. Table 2 presents characteristics of the two groups. Mean birth weight of patients who needed emergency repair was significantly lower than that of patients who underwent elective repair (1738 vs. 2001 g). Mean post conception age at the time of repair was 41 weeks (SD 3.2 weeks) in the emergency group and 44 weeks (SD 2.8 weeks) in the elective repair group ($p < 0.001$). Mean age at diagnosis was 53 days (SD 18 days) versus 53 days (SD 14 days; $p = 0.805$), respectively. Mean time between first presentation and repair was 18.0 days (SD 10.7 days) for elective repair and 1.8 days (SD 2.9 days) for emergency repair ($p < 0.001$). Mean weight at repair was

Table 2 Baseline characteristics

	Elective repair ($N = 94$)	Emergency repair ($N = 38$)	p value
Male gender (%)	78 (83)	35 (92)	0.273
Birth weight [g (SD)]	2001 (552)	1738 (483)	0.022**
Gestational age at repair [weeks (SD)]	44 (2.8)	41 (3.2)	<0.001**
Cardiac anomalies (%)	7 (8)	4 (11)	0.727
Bradycardia of prematurity (%)	7 (8)	8 (23)	0.034*
Apnoea of prematurity (%)	20 (23)	14 (40)	0.075
IRDS (%)	13 (15)	10 (29)	0.123
BPD (%)	2 (4)	4 (11)	0.056
History of mechanical ventilation (%)	26 (30)	18 (51)	0.036*
GERD (%)	5 (6)	4 (11)	0.276
NEC (%)	2 (2)	2 (6)	0.578

All values presented as percentages or means (standard deviations), p values are two-sided

IRDS infant respiratory distress syndrome, *BPD* bronchopulmonary dysplasia, *GERD* gastroesophageal reflux disease, *NEC* necrotising enterocolitis

* Statistically significant (Fisher exact test)

** Statistically significant (Mann–Whitney U test)

3912 g (SD 865 g) for elective repair and 3206 (SD 769 g) for the emergency repair ($p < 0.001$).

After elective surgery 48 out of 94 (51 %) patients were admitted to the NICU and after emergency repair 37 out of 38 (97 %; $p < 0.001$). Seven (18 %) patients needed prolonged mechanical ventilation at the NICU after emergency repair versus two (2 %) after elective repair ($p = 0.002$). The median duration of prolonged mechanical ventilation was 123 min (range 31; 2379 min). The recurrence rate after an emergency procedure was significantly higher than that after elective repair (13 vs. 2 %; $p = 0.021$).

Cost analysis

Based on the cost prices outlined in Table 1, the mean total costs per patient amounted to €5477 (SD €3280). Contributions of four different cost components to the total costs are outlined in Fig. 1. At mean €3573 (SD €3280), cost of hospitalizations made up two thirds of the total costs. The mean costs of the surgical procedures were €1385 (SD €1181), of perioperative consultation €107 (SD €92), and of OPC and/or ED visits €412 (SD €302).

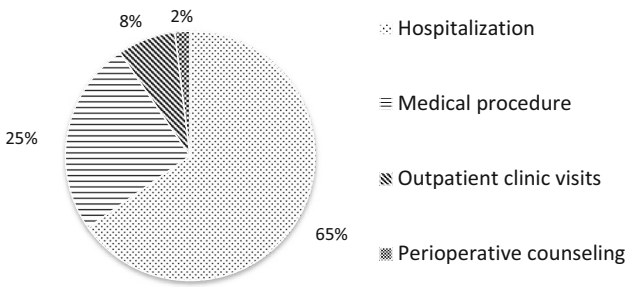

Fig. 1 Costs divided into four subcategories presented with percentages

Emergency repair resulted in 1.58 times higher total costs compared with elective repair: €7418 (SD €4484) versus €4693 (SD €3465; $p < 0.001$), respectively. These are further detailed in Table 3. Except for the costs of perioperative consultations, costs for all categories were higher on average in the case of emergency repair. The difference in costs of hospitalizations (€1501) accounted for more than half of the difference in total costs between the two patient groups (€2725).

When we controlled for possible confounding variables in the linear regression analysis (i.e., birth weight, age at repair, history of bradycardia, mechanical ventilation and emergency repair), the difference in total costs between emergency and elective repair remained €1183 (95 % CI −1196; 3044) in favor of elective repair. None of the variables included in the linear regression analysis were found to be contributing significantly to the total costs.

Discussion

Insight into the actual costs of different strategies in inguinal hernia repair would be relevant for planning and organization of care around premature infants with inguinal hernia. The present study is the first study that provides information about the true medical costs of inguinal hernia repair in premature infants, comparing elective and emergency repair. Emergency repair appeared to be associated with significantly higher direct medical costs.

Table 3 Difference in costs per patient between emergency and elective repair

	Elective repair (N=94)	Emergency repair (N=38)	Difference bootstrap (95% CI)
Pre-op high care- and medium care, € (SD)	164 (459)	271 (405)	107 (–52; 268)
NICU, € (SD)	2491 (1154)	3608 (1400)	1117 (643; 1651)
Post-op high- and medium care, € (SD)	328 (2415)	27 (167)	–301 (–872; 37)
Readmissions ward, € (SD)	91 (408)	452 (2339)	361 (–108; 1307)
Readmissions NICU, € (SD)	66 (447)	284 (1004)	218(–62; 591)
Hospitalization	**3141 (2986)**	**4642 (3746)**	**1501(283; 3050)**
Emergency department, € (SD)	136 (217)	274 (233)	138 (53; 222)
OPC first visits, € (SD)	180 (103)	113 (137)	–67 (–114; –18)
OPC follow up visits, € (SD)	52 (135)	69 (155)	17 (–37;77)
Telephonic consultation, € (SD)	19 (61)	28 (64)	10 (14;34)
Outpatient clinic visits	**388 (264)**	**485 (369)**	**66 (-35; 228)**
Ultrasound, € (SD)	8 (34)	28 (47)	20 (3; 38)
Preop. consultation anesthetist, € (SD)	114 (63)	43 (73)	–72 (–97; –47)
Perioperative consultation	**122 (84)**	**71 (100)**	**–52 (–85; –15)**
Operating room, € (SD)	562 (211)	686 (270)	124 (32; 230)
Operating room afterhours, € (SD)	–	746 (1037)	746 (435; 1071)
Reoperation, € (SD)	143 (727)	231 (589)	87 (–153; 336)
Surgeon,€ (SD)	170 (64)	207 (82)	37 (10; 69)
Surgeon afterhours, € (SD)	–	75 (104)	75 (44; 109)
Anesthetist, € (SD)	170 (64)	207 (82)	37 (10; 69)
Anesthetist afterhours, € (SD)	–	75 (104)	75 (44; 109)
Surgical procedures	**1045 (886)**	**2227 (1423)**	**1182 (754; 1660)**
Total costs, € (SD)	**4695 (3463)**	**7424 (4480)**	**2729 (1291; 4166)**

Costs in Euro for the first of January 2014, when 1 Euro (€) equalled approximately 1.38 US Dollar. All costs are rounded to whole Euro's. Nonparametric bootstrap techniques to derive a 95 % confidence interval were used CI is presented with lower and upper values between brackets

The values presented in bold are subcategories containing the sum of the aforementioned values

SD standard deviation, *NICU* neonatal intensive care unit, *OPC* outpatient clinic, *CI* confidence interval

Hospitalization was accountable for approximately two thirds of the total costs. Therefore, reducing length of stay on the ward and NICU could be an important target for cost reduction. The mean costs of hospitalization after elective repair were lower compared to costs after emergency repair. Almost all premature infants who had to undergo emergency repair were postoperatively admitted to the NICU and immediately discharged after overnight observation without admission to the high- or medium care unit. The question arises whether all patients should be admitted to the NICU postoperatively after an emergency procedure, or whether it would be possible to select only those who really need close observation. Very-low-birth weight premature infants with severe comorbidities are more likely to develop postoperative respiratory and cardiac incidents; obviously, a close observation or intervention on the NICU is advised for those [14–16]. The incarceration rate in our study population is relatively high compared to literature [2, 4, 17]. This can be explained by the fact that our hospital is the only tertiary academic pediatric hospital in the region and covers 4.5 million inhabitants. Our hospital is the only hospital in its region that is allowed to perform surgery in premature infants. Additionally, it also explains the relatively high recurrence rate because all patients with recurrences hernia will always return to our institution.

There were significant differences between the two study groups in pulmonary comorbidities, birth weight, weight at repair, age at repair, age at diagnosis and prolonged mechanical ventilation, which could be explained by the longer hospitalization and NICU stays in patients after emergency surgery. Still, preventing these patients from emergency repair could result in a reduction of costs.

Only one other study made a cost analysis of inguinal hernia in premature infants [7]. This study compared premature infants with full-term born infants, however, these groups are hardly comparable in terms of comorbidity, risk factors, and complications. In this study all premature patients underwent surgery with the use of general anesthesia. However, the use of spinal anesthesia alone can be advocated in patients with pre-existing diseases and incarceration undergoing inguinal hernia repair [18]. The costs of preoperative consultation of anaesthesiologist were significantly higher in the elective repair group. If patients were scheduled for elective repair, it was common practice in our hospital to consult an anaesthesiologist; in case of emergency surgery this was omitted.

The health- and peri-operative care around premature born infants have dramatically changed over the last three decades and new technical advances in neonatal surgery have driven up health care costs [10]. The policy to perform surgery during birth hospitalization before discharge from the NICU is still relevant, as this could prevent these neonates from readmissions and incarceration resulting in emergency surgery. Early herniotomy has already shown to improve postoperative outcomes without increasing postoperative bradycardia, apnea and other events [5]. Nevertheless, repair of inguinal hernia before discharge from the NICU is associated with a prolonged hospital stay [4]. Sufficient capacity, resources and a decision-making tool enabling surgery at least 1 week before planned discharge could solve this problem. Early surgery, on the other hand, is associated with a higher risk of surgical and anesthetic complications in view of the infant's lower body weight. The present study has limitations. Selection bias could have occurred due to the absence of a protocol on timing of inguinal hernia repair in premature infants. Furthermore, a financial analysis is dependant on the local financing process, and local institutional policies (e.g., in our institution, specialists' fees are similar during day and night shifts and admission to the NICU postoperative for patients under the gestational age of 40 weeks).

Keeping this limitation in mind, we provide solid evidence on the direct medical costs of emergency repair in premature infants. It appeared that emergency repair is almost 60 % more expensive than elective repair. Therefore, it can be argued that preventing premature infants from incarceration, for which often emergency repair is needed, will reduce aggregate direct medical costs. Further evidence on actual costs of different strategies in inguinal hernia repair in premature infants would be welcome as a basis for the development of decision-making tools. For instance, it would be worth knowing the additional costs of performing surgery during the birth hospitalization compared to the costs of elective surgery when delayed. Outcomes of new prospective randomized trials, including cost-effectiveness, will help allocate health care resources even more efficiently.

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Compliance with ethical standards

Conflict of interest The authors of this manuscript have no conflicts of interest to disclose.

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