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Inguinal hernia management in preterm infants: addressing current issues of interest

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Abstract: We define as preterm any newborn born before 37 weeks of gestation. The incidence of inguinal hernia is 1–4.4% among full term neonates and older children. In preterm newborns it is significantly more often, with an incidence that raises up to 30%. In this comprehensive review of the literature we provide evidence-based answers in various questions concerning the optimal treatment of inguinal hernias in preterm neonates. Such questions include the proper time of intervention, the choice of optimal anesthesia, the necessity for contralateral investigation in case of an ipsilateral hernia, the prevention of post-operative apnea and the choice between classic and laparoscopic surgical techniques.

Keywords: preterm infant, inguinal hernia, postoperative apnea, operative complications.

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Introduction

We define as preterm any newborn born before 37 weeks of gestation. The incidence of inguinal hernia is 1–4.4% among full term neonates and older children, while in preterm infants it is considered significantly more often, with an incidence ranging between 29.8 and 39% [1–3]. Regarding the localization of inguinal hernias, the classic theory of the increased incidence rate of right-sided hernias might not be valid (right-sided = 60%, left-sided = 30% and bilateral = 10%). In a study regarding the hernia occurrence it was reported that 39% of the inguinal hernias were right-sided, 31%

were left-sided and 30% bilateral [4]. In addition, a higher incidence of inguinal hernia has been reported for males, likewise with older children (male to female ratio: 7–8/1) [1–3].

According to the classic theory, when an infant was diagnosed with inguinal hernia, it had to be treated as soon as possible, in order to avoid the incarceration of the herniated tissue. The risk of incarceration is estimated to affect no less than 30% of infants during the first six months of life. However, in preterm infants, the complication rate is even higher [5].

Preterm infants have a moderately higher risk for developing postoperative serious complications, especially respiratory ones, while the latter complication rate is ten times higher when compared to full-term infants [6].

Preterm infants are classified as high-risk patients, mainly because of the underlying morbidities. The most usual morbidities are respiratory distress syndrome (RDS), bronchopulmonary dysplasia (BPD), necrotizing enterocolitis (NEC), anaemia, congenital heart diseases, patent ductus arteriosus and intraventricular hemorrhage.

The hernia sac in preterm infants is usually thin-layered and oedematous, for the dissection of which a skilled and experienced surgeon is required, because if it is inadvertently opened, the risk for recurrence becomes even higher. Analysing the relevant bibliographic data, higher rates of hernia recurrence are observed among preterm infants, varying from 5 to 14.1% [3, 4].

Vogels *et al.* have attributed the high recurrence rate (62.5%) to the larger hernial sac, the inadvertent opening of hernial sac during dissection, the early gestation infants and underlying co-morbidities, with emphasis on a history of assisted ventilation or a ventriculoperitoneal shunt [7].

According to Lautz *et al.* [8], if the inguinal hernia is repaired early, the hernia sac is small and easier to be separated from the spermatic cord. This ascertainment seems to be associated with the maternal and cord blood progesterone concentrations in preterm infants [8].

Aim of the review

We aim, after a comprehensive and thorough search of the relevant available literature with emphasis on the most recent evidence, at addressing evidence-based answers about the remaining issues concerning the management of the inguinal hernia in preterm infants.

Such issues are: (a) the minimum post-conceptual age, (b) considerations regarding anaesthesia (general anaesthesia, regional anaesthesia or combination), (c) the necessity for contralateral investigation in case of an ipsilateral hernia, (d) the prevention of post-operative apnea and (e) the choice between classic and laparoscopic techniques.

Time of intervention

Determination of the proper time for the surgical repair of an inguinal hernia still remains conflicting. Early management encompasses a high risk for intra- or post-operative complications, and also for the exacerbation of the underlying pathology of the infant. Delayed management is associated with a high risk for incarceration of the hernia, and its consequences to the herniated tissue, the ipsilateral testicle and the destabilization of the infant.

There are two main trends regarding the most appropriate time for intervention, the early and the delayed ones. Advocates of early intervention believe that the inguinal hernia should be treated before the infant leaves the Neonatal Intensive Care Unit (NICU). On the contrary, those advocating delayed intervention believe that surgery should be done later, when risk for complications from the general anaesthesia is substantially reduced.

Two viewpoints have been expressed regarding the early intervention. According to the first, the inguinal hernia treatment should be established relatively soon and within one week from the diagnosis. According to the most conservative one, the treatment of inguinal hernia should be done shortly before the preterm neonate leaves the hospital. Antonoff *et al.* analyzed the relevant answers given by the members of the American Society of Pediatric Surgeons [9]. It was shown that 63% of the pediatric surgeons would perform the operation shortly before the discharge of the preterm neonate from the NICU, 5% would perform it soon after the diagnosis and 18% when the intervention secured the least possible surgical risk. If the preterm neonate was discharged from the hospital and was suffering from inguinal hernia, then 53% of the pediatric surgeons would treat it very soon, while 27% would treat it later, in order to complete 53 weeks of corrected age of the preterm neonate.

In a retrospective study by Vaos *et al.* [3], the results after the treatment of inguinal hernia in preterm neonates hospitalized in NICU were evaluated and were subdivided into 2 groups based on the time of treatment from the diagnosis. Group A (short wait, less than one week after the diagnosis of inguinal hernia) included 25 preterm neonates aged 28–35 weeks, while Group B (longer than 7 days waiting from the diagnosis of inguinal hernia) included 16 preterm neonates aged 30–55 weeks. There were 12 episodes of incarceration in total, which were divided into 3/25 in group A (12%) and 9/16 in group B (56%). Postoperative apnea developed in 6/41 patients: 4/25 in group A and 2/16 in group B. There were 5/41 relapses, from which 1/25 occurred in group A and 4/16 in group B. Finally, testicular atrophy was found in 4 cases, 1/25 in group A and 3/16 in group B. Therefore, delaying treatment dramatically increases the risk of incarceration by 4.7 times. In conclusion, it is suggested that inguinal hernia in preterm neonates should be treated as soon as possible after diagnosis.

On the contrary, Crankson *et al.* [4] treated early 84 preterm neonates with inguinal hernia. Based on the time of the operation, the cases were classified into 2 groups: group A consisting of 23 preterm neonates with a total postconceptional age (PCA) of 39.5 ± 3.05 weeks, which were treated before leaving NICU, and group B consisting of the remaining 61 preterm neonates with PCA 66.5 ± 42.73 weeks, which were discharged from NICU and were re-admitted to the hospital. Preterm neonates of group A essentially met the NICU discharge criteria, such as:

- 1) body weight greater than 1,750 grams
- 2) no apnea episode occurred during the previous 7 days
- 3) do not receive oxygen or theophylline for at least 72 hours
- 4) fed by mouth with a positive fluid balance and finally
- 5) is able to maintain vital signs without support.

No cases of incarceration of the inguinal hernia or postoperative apnea episodes were documented. Of the 61 preterm neonates in group B, 47 (77%) were discharged from the hospital on the day of surgery, while the remaining 14 (23%) remained hospitalized. Therefore, it is suggested that inguinal hernia should be treated early before the discharge of preterm neonates from NICU. This strategy is the most suitable, as it does not substantially increase the probability of incarceration and postoperative apnea occurrence.

Lautz *et al.* [8] treated a total of 1,123 preterm neonates with inguinal hernia. The incidence of incarceration was 16%. The incidence of incarceration among preterm neonates with high body weight in relation to age (LGA) was 56% compared to 12% among those with low body weight in relation to age (SGA). In addition, they noticed that the incidence of incarceration increases over time (9% in PCA 36–39 weeks versus 21% in PCA >40 weeks). Notably, delay of surgical intervention by a month increases the risk of incarceration by 2.33 times. Thus, they point out the necessity of the early management of inguinal hernia.

Takahashi Aka *et al.* [10] performed 14 herniotomies in preterm neonates early before their discharge from NICU and 33 late after their discharge from NICU. Then they compared the results of these 2 groups, utilizing as control a third group consisting of 52 full-term newborns. Difficulty in patient's awakening after the operation was observed in 4/47 preterm neonates, however in none among the full-term neonates. Iatrogenic cryptorchidism was observed in 2/47 preterm neonates and in one full-term neonate. None of the aforementioned complications reached statistical significance among the three groups. In conclusion, they suggest that the delayed treatment of inguinal hernia in the preterm neonates is preferable.

Lee *et al.* [11] performed 172 scheduled herniotomies in preterm neonates, with a mean age of 30.7 weeks and an average body weight of 1.428 kilograms. At the time of surgery, the mean PCA was 46.6 weeks and the mean weight was 3.688 kilograms. Thirty-five preterm neonates were discharged from NICU with a diagnosis of inguinal

hernia and returned for a scheduled herniotomy, without any episode of incarceration in the meantime. There were no episodes of postoperative apnea. There was a total of 8/172 (4.6%) events of incarceration, of which 3 represented the initial clinical manifestation of inguinal hernia and the remaining 5 occurred after the initial diagnosis, but before the discharge from NICU. In 45/172 preterm neonates the herniotomy was performed before discharge from NICU. In these patients, prolonged hospitalization was observed postoperatively by 2–51 days (average length of hospitalization: 8 days). According to the authors, the risk of incarceration seems to be lower than previously reported, while the early treatment of inguinal hernia leads to prolonged hospitalization in the postoperative period.

Issus regarding anesthesia

An important development in the corresponding field is the application of dorsal anesthesia to these pediatric patients, substantially reducing — almost by 66% — the risk of postoperative apnea. This method is considered as effective in achieving — both intraoperatively and postoperatively — adequate analgesia without increasing the risk for postoperative apnea, bradycardia or desaturation and postoperative respiratory support. However, epidural anesthesia cannot be applied to laparoscopic inguinal hernia repair methods.

Frumiento *et al.* [12] attempted to correlate the type of anesthesia with the postoperative apnea incidence. They applied spinal anesthesia in 262/269 preterm neonates with an average body weight of 1.688 kilograms, an average gestational age of 32 weeks and average PCA of 43.7 weeks, respectively. In 153/262 preterm neonates a history of apnea episodes was reported. In 206/262 patients (78.6%) no additional anesthesia intervention was required to complete the surgery, which lasted for an average of 26.3 minutes. On the contrary, the remaining 56 (21.4%) preterm neonates required additional anesthesia. Postoperative apnea was documented in 13/262 preterm neonates (4.9%). Therefore, the authors concluded the following:

- 1) the incidence of postoperative apnea is lower than previously reported
- 2) in the group of preterm neonates at low risk for developing postoperative apnea (average weight 2.091 kilograms, average gestational age 33 weeks and mean PCA 44.3 weeks) the strategy of discharge from the hospital on the day of surgery may be considered as generally safe.
- 3) performing dorsal anesthesia on preterm neonates with an increased risk for postoperative apnea, the risk remains high when ketamine is administered. However, if epidural anesthesia is not combined with ketamine administration, then the risk is considered negligible.

The “answer” to general anesthesia, however, can be obtained through the development of new anesthetic drugs that are rapidly metabolized. However, reservations

about the neurotoxicity of these anesthetics — regarding the potential effects of anesthetics on the developing brain — and the risk of postoperative apnea remain unknown, at least until large prospective studies are published.

Classic or laparoscopic approach?

There is no consensus regarding the appropriate surgical approach for treating inguinal hernia, as the arguments regarding the advantages and disadvantages of each option have been documented in detail.

Enthusiasts of laparoscopic approach emphasize on the possibility of simultaneous examination of the unilateral inguinal canal, thus reducing the need for a second surgery later. They also consider that the risk of iatrogenic injury to the content of the spermatic cord is significantly lower, compared to the classic method.

The reservations against the choice of laparoscopic approach are [13]:

- 1) development of pneumoperitoneum that may exacerbate premature lung function
- 2) the very small peritoneal cavity that limits the range of motion
- 3) an extraperitoneal operation is essentially transformed into intraperitoneal
- 4) general anesthesia is required in contrast to the open method that can be performed with epidural anesthesia, a choice that is particularly important in high-risk preterm neonates
- 5) the higher equipment cost
- 6) the required learning curve

Moreover, the laparoscopic approach requires a longer period of time and is not advantageous in terms of the aesthetic result.

These general limitations, despite the fact that there is an increased probability of complications induced by anesthesia equal to 5–12%, are not fully accepted by involved physicians.

Esposito *et al.* [14] treated laparoscopically 67 neonates weighing less than 3 kilograms (mean body weight: 2.6 kilograms), out of whom 15 (22.3%) presented with incarceration. In 3 patients (4%) recurrence was documented postoperatively while in 12 patients (25.55%) an iatrogenic retractile testis was found.

Turial *et al.* [15] treated laparoscopically 147 newborns (100 male — 47 female) with a body weight of 1.45–5 kilograms (mean body weight: 3.9 kilograms), suffering from inguinal hernia, 58 out of whom (39.4%) were preterm and suffered from incarcerated inguinal hernia. The mean duration of each bilateral operation was 20 minutes, while no complications were reported. During the 26-month postoperative follow-up period, 4 cases of recurrence (2%) and 5 (5%) cases of iatrogenic cryptorchidism were reported, while no case of testicular atrophy was documented. The probability of inguinal hernia recurrence was shown to be increased (14.16%). Based on the

linear regression analysis it was proven that the lower the weight of the newborn undergoing laparoscopic management of inguinal hernia, the greater the probability of iatrogenic cryptorchidism is.

Chan *et al.* [16] treated laparoscopically 79 preterm neonates with inguinal hernia (18 unilateral and 51 bilateral) without reporting any complications. The mean duration of operation was 46 minutes. They followed-up those patients postoperatively for 7 years, reporting only one case of recurrence.

Pastore and Bartoli [17] treated laparoscopically 28 preterm neonates with inguinal hernia without reporting any intraoperative or postoperative complications. The mean duration of each operation was 30 minutes for unilateral inguinal hernia and 41 minutes for bilateral. In the 21-month postoperative follow-up period, no recurrence was reported.

Based on the aforementioned data, we sum up the following:

- 1) an increased incidence of complications during induction of anesthesia in the performed laparoscopic surgeries is documented,
- 2) an increased incidence of iatrogenic cryptorchidism, possibly due to the retraction of the spermatic cord from the ligation of the hernia sac at the height of the internal inguinal ring has been shown,
- 3) there is no chance of developing testicular atrophy in inguinal hernia cases, concerning the affected testis. However, the latter finding should be interpreted with caution due to the short duration of postoperative follow-up in the included studies. It is well established that the testicles develop at a very slow rate from birth to 9 years of age, in contrast to pre-adolescence and adolescence (10–18 years), when their dimensions increase by 2–4 times, due to the activation of the hypothalamic-pituitary-gonadal axis.

Unilateral exploration

In the past, exploration of the unilateral groin in one-sided inguinal hernias in preterm neonates was a practice followed by several pediatric surgeons [18]. Enthusiasts of the laparoscopic approach came back to this issue recently, as it is a comparative advantage to be able to control and simultaneously correct the pathology of the processus vaginalis unilaterally. The exploration of the unilateral groin increases duration of surgery and the risk for iatrogenic injury in the contents of the spermatic cord. Prolongation of the operation may increase the risk for postoperative apnea. Besides, the patency of the processus vaginalis does not necessarily imply the development of inguinal hernia in the future.

In one of the largest available observational studies, Steven *et al.* [19] encountered 172 preterm neonates with inguinal hernia (162 males and 10 females) with a mean gestational age of 31 weeks and a mean age at the time of surgery of 66.5 days. In 32

preterm neonates (18.6%) bilateral inguinal hernia was found preoperatively. In 18 preterm neonates (10.4%) surgery was performed on an urgent basis due to incarceration. In 77 neonates, the unilateral groin was explored (group A) while in 63 neonates, it was not (group B). Of the 63 patients in group B, 9 (14.3%) developed postoperative inguinal hernia unilaterally. Postoperative follow-up lasted from 33 days to 5.5 years (mean 2.83 years), while the mean time of development of the unilateral inguinal hernia was 24 days. They also demonstrated that the classic approach does not apply, i.e. if the unilateral inguinal hernia is left-sided then there is a greater probability of a right-sided inguinal hernia occurrence. In fact, they showed exactly the opposite. For this reason, the authors do not suggest the exploration of the unilateral groin in preterm neonates, when dealing with one-sided inguinal hernia.

Marulaiah *et al.* [20] conducted a prospective study to assess the need to explore the groin site unilaterally, during the management of unilateral inguinal hernia in 105 preterm (group A) and 161 full-term neonates (group B). Preoperative development of bilateral inguinal hernia occurred in 10% of group A and 6% of group B. They therefore showed that there was no statistically significant difference in the incidence of bilateral inguinal hernia between the 2 groups, with the exception of the very young for gestational age (VSGA) and the preterm neonates that were treated early. Therefore, they do not suggest the routine exploration of the unilateral groin.

In conclusion, it is worth emphasizing the following:

- 1) the incidence of inguinal hernia incarceration in preterm neonates is not as high as it was believed in the recent past (10–11% vs. 30%)
- 2) maintaining the processus vaginalis open does not predict that inguinal hernia will develop in the future. The probability of development of inguinal hernia unilaterally ranges from 7–14.8% [19, 20].
- 3) the increased possibility of iatrogenic injury of the contents of the spermatic cord should not be ruled out during the treatment of inguinal hernia in preterm neonates. The probability of injury of the vas deferens is estimated to be 0.2–1.6% [21, 22] while of testicular atrophy 2–30% [23].
- 4) after surgical treatment of unilateral inguinal hernia in preterm neonates, the pediatric surgeon should perform a thorough follow-up with short time intervals, in order to diagnose early the development of unilateral inguinal hernia.
- 5) it is clear that the publication of forthcoming studies [Minimal Access Repair of Contralateral Hernias (MARCH) Trial] will provide further insights into the ultimate results of laparoscopic treatment of inguinal hernias in preterm neonates, promising to answer the issue raised regarding the necessity of bilateral exploration.

Postoperative apnea

The term apnea is defined as the cessation of breathing for at least 15 seconds or less if it is accompanied with bradycardia and paleness. Apnea is considered severe when it causes desaturation (Sat O₂ <85%) or it is necessary to apply a special apnea mask to support preterm neonate's breathing.

The risk for postoperative apnea and bradycardia remains a significant problem, although the ability to support the preterm neonate in NICU in the postoperative period has limited its complications. Based on the classic relevant literature, the incidence of postoperative apnea in preterm neonates undergoing inguinal hernia rehabilitation reaches up to 49% [12, 24].

In recent studies, however, this probability is estimated to be 5%, i.e. 10 times lower [12]. This is mainly attributed to the evolution of anesthesia. However, it has been documented that administration of analgesic drugs, induction of general anesthesia and prolonged surgery can increase the incidence of postoperative apnea.

Based on the most recent relevant literature, it is demonstrated that the probability of developing postoperative apnea is inversely related to the age and PCA of the affected preterm neonate.

Walther-Larsen and Rasmussen [25] in their meta-analysis estimated that preterm neonates with PCA <46 weeks should be monitored postoperatively for at least 12 hours. In contrast, preterm neonates with PCA ranging between 46 and 60 weeks, the indication for close monitoring postoperatively must be individualized and based on the potential risk for developing postoperative apnea as a consequence of co-existing conditions. In addition, they recommend the preclusive administration of caffeine (10 mg/kilogram of body weight), in order to reduce the chance of an postoperative apnea episode.

Murphy *et al.* [26] treated 126 preterm neonates with inguinal hernia. Six out of 126 (4.8%) developed postoperative apnea. The latter manifested either early, i.e. within the first 6–13 hours (mean 11 hours) or relatively late, i.e. within the first 13–56 hours (mean 24 hours) from the end of the operation. They also identified potential risk factors for the onset of postoperative apnea, such as preoperative apnea episodes, lower gestational age, low birth weight, bronchopulmonary dysplasia, intraventricular hemorrhage, patent ductus arteriosus, need for mechanical support of breathing preoperatively, anemia and finally increased requirements for oxygen supplementation preoperatively. They believe that modern inhaled anesthetic drugs have helped to reduce the risk for developing postoperative apnea. They therefore suggest the close monitoring of high-risk preterm neonates that undergo surgery for 24 hours.

Ozdemir and Arkan [27] managed 428 preterm neonates with inguinal hernia. Based on the PCA they were classified into 2 groups: group A consisting of 191

preterm neonates with PCA <45 weeks and group B consisting of 237 with PCA between 45 and 60 weeks. The incidence of postoperative apnea in group A was 4.7% while in group B it was 0.8%, i.e. 6 times higher in group A. The main causes for the development of postoperative apnea in group B were anemia, necrotic enterocolitis and bronchopulmonary dysplasia.

The conclusions reached by the authors [27] are the following:

- 1) close overnight monitoring is required in all preterm neonates with PCA <45 weeks as well as in those with PCA >45 weeks, when the aforementioned risk factors are met
- 2) the risk of postoperative apnea lasts 12–18 hours
- 3) preterm neonates with a low risk for developing postoperative apnea should be monitored postoperatively for 6 hours and then — if they are uncomplicated — they can be discharged from the hospital.

Laituri *et al.* [24] surgically treated 363 preterm neonates with inguinal hernia. Based on PCA, they were classified into 3 groups, group A consisting of 23 neonates with PCA <40 weeks, group B consisting of 244 neonates with PCA between 40 and 49 weeks and finally group C consisting of 96 neonates with PCA >50 weeks. They showed that the lower the PCA of the neonate the greater the risk for postoperative apnea is. More specifically, this probability was determined to be 44% in group A, 21% in group B and 16% in group C. They suggested the close monitoring of the treated neonate for the remaining 24 hours, if PCA is <50 weeks.

Finally, Crankson *et al.* [4] believe that the treatment of inguinal hernia in preterm neonates with PCA >47 weeks can be performed safely without requiring hospitalization, while Lee *et al.* [11] have suggested that inguinal hernias should be treated without hospitalization in neonates with PCA >41 weeks.

Concluding remarks

Based on the aforementioned data, two trends have been developed for the treatment of inguinal hernia in preterm neonates. According to the first trend, parents are advised for the surgical repair of the inguinal hernia before the neonate leaves the neonatology department, while according to the second, the child is discharged from the hospital and the inguinal hernia is treated later on a routine basis, when the surgery is considered as safer. Each strategy should be discussed in detail with the parents who have to make the final decision.

However, if it is a symptomatic inguinal hernia, when the correction of the hernia is considered as difficult, the cooperation with the parents is hard or finally there is no short access to a specialized center, then the inguinal hernia should be treated before the preterm neonate is discharged from the neonatology department.

Conflict of interest

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