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Risk factors of early mortality after neonatal surgery in Tunisia

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ABSTRACT

Background: Research concerning factors of death after neonatal surgery is scarce. Insight into mortality might improve perioperative care. This study aimed to identify predictive factors of mortality after neonatal surgery in a low income country (LIC).

Methods: Charts of all newborn patients who underwent surgical procedures under general anesthesia during the neonatal period in our department of pediatric surgery between January 2010 and December 2017 were reviewed. We used univariate and multivariate analysis to evaluate perioperative variables potentially predictive of early postoperative mortality.

Results: One hundred eighty-two cases were included in the study: 41 newborns (28.6%) were premature (<37 weeks of gestation) and 52 (22.5%) weighed less than 2.5 kg. The most commonly diagnosed conditions were esophageal atresia (24%) and bowel obstruction (19%).

Forty-four patients (24%) died during hospitalization. The highest rate of mortality was observed for congenital diaphragmatic hernia. Univariate analysis showed that perinatal predictive variables of mortality were prematurity, low birth weight, the necessity of preoperative intubation, and duration of surgery more than 2 h. Logistic regression showed three independent risk factors, which are the duration of surgery, low birth weight and the necessity of preoperative intubation.

Conclusion: The overall mortality in infants undergoing neonatal surgery is still high in LICs.

Knowledge of independent risk factors of early mortality may help clinicians to more adequately manage the high-risk population.

Type of the study: Clinical research paper.

Level of evidence: III.

Annually, 4 million children worldwide die in the first month of life [1]. Sub-Saharan Africa handles the largest increase in the proportion of neonatal mortality in low and middle-income countries (LMICs) [2]. Despite the improvement in surgical techniques anesthesia and neonatal care, neonatal surgery still presents a challenging component of pediatric surgery [3–5]. In fact, neonatal surgery is associated with higher postoperative mortality than in children [6,7]. Little is known about the effect of neonatal surgical conditions on the overall mortality and there is a little research concerning the factors of death after neonatal surgery in LMICs [8–12].

A systematic review and meta-analysis of outcomes after neonatal surgery in Africa found that the overall mortality in the last ten years was 29.1% with a few papers meeting inclusion criteria [13]. Perioperative care is a priority topic in LMICs [14]. Insight into mortality among operated newborn might improve perioperative care. This study aimed to identify predictive factors of early mortality after neonatal surgery in Tunisia.

1. Patients and methods

We conducted a retrospective study of collected records from archives of the department of pediatric surgery and neonatology in Hedi Chaker Hospital of all operated neonates (0 to 30 days) under general anesthesia between January 2010 and December 2017. Approval form was obtained from the Hedi Chaker Hospital institutional review board.

Hedi Chaker Hospital is a public structure located in Sfax, which is the second biggest city in Tunisia. Patients who have health insurance in Tunisia benefit from a symbolic contribution to the health care fees unlike private hospitals where patients pay all the hospital care costs.

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The department of pediatric surgery of Sfax is the fifth and the newest built department of pediatric surgery in Tunisia. It's the sole public provider of neonatal surgery in the south of Tunisia. The computer storage of medical information began in 2010 in the department of pediatric surgery. That's why we began the study in 2010.

In the department of pediatric surgery of Sfax, there was no infant ventilator except anesthesia machines from the operating room. The postoperative neonatal care was performed in the neonatal care unit located in another building (maternity building) located in the front of the department of pediatric surgery. The newborns got medical transfer from neonatal unit to perform surgery then went back to the department of neonatology at the end of the surgery where pediatric surgeons and neonatologists took care of them. There were 5 seniors of neonatology and 4 trainees during the study period. Three adult anesthesia consultants and 3 postgraduate trainees provided anesthesia. The number of pediatric surgeons increased from 30 surgeons in the country in 2010 to about 60 in 2017. Half of these surgeons spent one or two years of their training in France to improve their performances. There were about 350 pediatric surgeons in France in 2018 with a density of one pediatric surgeon for 200,000 children. The number of senior consultants in Sfax was 3 till 2015 and 5 till 2017 for a population of the south of about 5 million habitants. The number of trainees was 3 in 2010 and increased to 6 in 2017.

In case of prenatal diagnosis, there was no antenatal unit or staff but neonatologists were informed just before the birth and they planned the medical transfer and the time of surgery with surgeons and anesthetists. Neonatologists decided if preoperative intubation was necessary. The surgeries were scheduled during the day. No emergent surgery was performed after 7 pm because of the lack of sufficient number of anesthetists, technicians of anesthesia and instrumentalists. In case of emergent night surgery, the newborn was transferred to one of the four other departments located in the north of the country.

Patients who were excluded from the study were those with insufficient data in the hospital chart or lost during follow up, patients who were not operated under general anesthesia or were not operated in our department or dead before surgery and cases with no parental consent. Cardiac surgery and neurosurgery were not performed in our department.

Preterm birth was defined as birth less than 37 weeks of gestation, and low birth was defined as a weight less than 2.5 kg. Early postoperative complication or mortality was defined as the occurrence of at least one complication or death during the 30 days after surgery.

1.1. Variables collected

Preoperative variables: antenatal diagnosis, intrauterine growth restriction, pregnancy term, birth weight, gender, associated malformations, time of diagnosis and preoperative intubation for respiratory distress before surgery.

Intraoperative variables: surgical procedure and duration of the surgery. Postoperative variables: duration of intubation, the occurrence of postoperative complications, death and duration of hospital stay.

1.2. Statistical analysis

Preoperative variables, surgical variables, postoperative variables and outcomes were analyzed using descriptive statistics. Statistical analyses were performed using IBM SPSS statistics 20. Categorical data are summarized as absolute values (percentage). Continuous data were presented as median, mean and range. Univariate then multivariate analyses were performed to determine independent perioperative factors associated with 30-day postoperative mortality. Comparisons between groups were done with a Student-test for continuous variables and chi^2 test for countable variables. A logistic binary regression model was used to determine perioperative predictive factors of 30-day postoperative mortality. Characteristics not significantly associated with mortality were excluded from our model of logistic regression analysis to avoid reducing statistical relevance. P-value less than 0.05 was considered statistically significant.

2. Results

During the study period, 226 newborns that needed surgery were admitted in the department of neonatology. Two hundred and one patients were operated in the department of pediatric surgery. There were 170 inborn and 31 outborn babies. Twenty-five patients died before surgery and were mainly outborn babies who came from regional hospitals. Surgical conditions of patients who died before surgery were as follows: diaphragmatic hernia with respiratory insufficiency, 6; severe enterocolitis, 6; esophageal atresia, 4 (2 VACTERL syndrome and 2 patients with late diagnosis and respiratory insufficiency); giant omphaloceles, 3; volvulus with late diagnosis, 3; small bowel obstructions with late diagnosis and severe sepsis, 3. Nineteen other patients who lived were excluded and 182 patients were enrolled in the study.

2.1. Patients and operative characteristics

There were 126 males and 56 females (sex ratio: 2.25). Pregnancy was well followed in 150 cases (82.4%). Thirty-eight cases (20.9%) had an antenatal diagnosis using obstetrical ultrasound. Fifty-two newborns (28.6%) weighed less than 2.500 kg and forty-one (22.5%) were premature. Characteristics of the newborns are detailed in Table 1.

Various neonatal conditions, surgical procedures and rates of mortality are detailed in Table 2. Esophageal atresia (24.2%) and small bowel atresia (19.2%) were the most common surgical conditions. Table 4 shows the mortality rates among different neonatal conditions. The highest mortality rate was reported for severe enterocolitis then neonatal diaphragmatic hernia (41.6%) followed by small bowel obstruction (37%).

Table 1
Characteristics of patients at birth.

Characteristics of patients:	*N*	%
Consanguinity		
No	94	51.6
Yes	36	19.8
Not mentioned	52	28.6
Antenatal diagnosis		
No	144	79.1
Yes	38	20.9
Gender		
Male	126	69.2
Female	56	30.8
Birth weight in grams (mean 2800, median 2900, range 1000–4200)		
<1500	4	2.2
1500–2499	43	23.6
≥2500	135	74.2
Gestational age in weeks (mean 37.4, median 38, range 30–42)		
<32	5	2.7
32–37	70	38.5
>37	107	58.8
Apgar (mean 8.14, median 8, range 2–9)		
≥7	139	76.4
<7	11	6
Not mentioned	32	17.6
Age at the presentation in hours (mean 37.2 h, median 48 h)		
0–168	169	92.8
>168	13	7.1
Other associated malformations		
No	121	66.5
Yes	61	33.5

Table 2
Mortality rate among various surgical conditions.

Neonatal condition	Number	Surgical treatment (*n*)	Nonfatal complications: *n* (%)	Mortality: *n* (%)
Esophageal atresia	44	- Anastomosis (41) - Stoma (3)	18	10 (22.7)
Small bowel atresia	35	- Anastomosis (34) - Stoma (1)	17	13 (37.1)
Diaphragmatic Hernia	24	Defect closure (24)	9	**10 (41.6**)
Anorectal malformation:			1	1 (3.3)
-Intermediate/high	11	-Stoma (11)		
-Low	19	-Anoplasty (19)		
Omphalocele	19	Primary closure (19)	8	2 (10.5)
Hirschsprung	5	-Stoma (4) -Surgical rectal biopsy (1)	1	1 (20)
Posterior urethral valves	9	-Urinary diversion (5) -Electroincision (4)	3	1 (11)
Testicular torsion	6	Orchidectomy/orchidopexy	0	0(0)
Enterocolitis (perforated)	6	Stoma (6)	2	**4 (66.7)**
Enteric duplication	1	Resection and anastomosis	1	1(100)
Renal cystic lymphangioma	1	Excision		0 (0)
Pyloric hypertrophic stenosis	1	Ramsted's pyloromytomy	1	1(100)
Neurogenic bladder		Urinary diversion	0	0 (0)
Total	182		61 (33.5)	44 (24.2)

2.2. Perioperative complications and mortality

The mean duration of hospitalization was 14.7 days (median: 12, range: 1–90). Sixty-one patients (33.5%) had complicated evolution. Six of the patients who had complicated evolution needed an early second surgery (3.3%). Nonfatal complications (specific and nonspecific ones) are detailed in Table 3. The main complications were hospital acquired infections and cardiac or respiratory insufficiency.

Forty-four patients (24.2%) died within the first postoperative month. The average time of early death after surgery was 9 days (range: 0–30). Table 3 shows the causes of death for these 44 patients.

2.3. Factors associated with mortality

The univariate analysis showed that the presence of preterm birth, the low birth weight, the respiratory distress, the necessity of preoperative intubation and the duration of surgery (more than 2 h) were significantly associated with mortality (Table 4). These factors, which were significantly associated with mortality, were included in the model of the logistic regression analysis. On the multivariate analysis, three factors remain significant: the low birth weight with the most important odds ratio (OR = 5.917 CI [2.597–13.478]), then the preoperative intubation (OR = 3.611 CI [1.462–8.918]) and the duration of surgery >2 h (OR = 5.791 CI [2.548–13.162]). The mean follow-up period of survivors was 41 months (range: 12–94 months).

Table 3
Early nonfatal complications and causes of deaths among newborns.

Complications	Nonfatal complications *n*	%	Causes of death *n*	%
Severe sepsis secondary to hospital acquired infection	**19**	31.2	**16**	36.3
Convulsion	4	6.7	2	4.6
Cardiac insufficiency	7	11.5	7	15.9
Respiratory insufficiency	**13**	21.3	**13**	29.6
Anastomotic fistula or peritonitis	5	8.2	3	6.8
Metabolic	7	11.5	3	6.8
Hemorrhage	1	1.6	0	0
Bowel obstruction	1	1.6	0	0
Intestinal intussusception	1	1.6	0	0
Evisceration	1	1.6	0	0
Prolapsed stoma	1	1.6	0	0
Urinoma	1	1.6	0	0
Total	61	100	44	100

3. Discussion

With a large cohort of ill neonates from a North African country undergoing surgical procedures in a tertiary hospital, the present study gave insight into the pattern of neonatal surgical conditions and showed a high overall early mortality. Preoperative mortality was mainly owing to late diagnosis in secondary care centers. The major causes of mortality after surgery were severe sepsis, cardiac insufficiency and respiratory insufficiency. Independent risk factors of mortality were the low birth weight, the necessity of preoperative intubation and the duration of surgery.

Table 4
Characteristics of infants who died during hospitalization and infants who survived and their association with mortality.

Variables	30-day mortality		OR CI 95%	p-value
	No *n* (%)	Yes *n* (%)		
Gender:				
Male	97 (77)	29 (23)	-	0.58
Female	41 (73.2)	15 (26.8)		
Term:				
<37	28 (59.6)	19 (40.4)	2.98	**0.003**
≥37	110 (81.5)	25 (18.5)	[1.44–6.17]	
Weight:				
<2500	23 (48.9)	24 (51.1)	6	<**0.0001**
≥2500	115 (85.2)	20 (14.8)	[2.8–12.6]	
Congenital malformation:				
No	93 (76.9)	28 (23.1)	-	0.64
Yes	45 (73.8)	16 (26.2)		
Preoperative intubation:				
Yes	26 (63.4)	15 (36.6)	2.22	**0.035**
No	112 (79.4)	29 (20.6)	[1.04–4.74]	
Age at surgery:				
≥ 8 days	15 (68.2)	7 (31.8)	-	0,372
< 8 days	123 (76.9)	37 (23.1)		
Duration of the surgery:				
≤2 h	109 (85.2)	18 (17.8)	5.42	<**0,0001**
>2 h	29 (52.7)	26 (47.3)	[2.62–11.23]	
Type of surgery:				
Thoracic surgery	34 (66.7)	17 (33.3)	-	0.53
Abdominal surgery	98 (81)	23 (19)		
Urologic surgery	6 (60)	4 (40)		

In our study males were predominant, similar to other studies [9,10]. A small number of population-based studies have examined the etiology of sex differences among newborns with birth defects [15]. This may be explained by the details of the reproductive functions or the influence of environmental and social factors. Some authors suggested the theory of a "selective loss in utero" [16].

The overall mortality rate was high compared to recent publications from developed countries, where mortality is below 10% [6,9,17]. This rate was however similar to other limited resources countries series [8–11,17]. The high mortality in LICs studies was a consequence of limited economic conditions and social factors [8,18,19]. In our series, firstly, the low rate of antenatal diagnosis deprived newborns of the advantages of planning birth close to or within a tertiary pediatric center. Secondly, the late recognition and referral of the birth defects may lead to the increase of morbidity like respiratory insufficiency, cardiac failure, sepsis and the need of preoperative intubation. This may also explain the high preoperative and postoperative mortality in outborn patients who came from intermediate care centers in our series. Thirdly, the limited number of health care professionals and a dearth of trained personnel with inadequate healthcare funding may intervene. The fact that the two departments of neonatology and pediatric surgery are located in different buildings raises the risk of instability during the transfer to the operative room and the return may increase perioperative morbidity. A high rate of deaths caused by neonatal sepsis was also observed. Death in babies weighing less than 2.5 kg was important although there were only six severe preterm babies weighing less than 1.5 kg. This may be explained by a lack of hygiene measures associated with the precarious state of babies.

The most common surgical disease was esophageal atresia, which was comparable to another conducted study in India [12]. However, there were no cases of gastroschisis. The nonexposition during pregnancy to risk factors should be sought (smoking, drinking alcohol…). A high rate of mortality was also noted in infants with congenital diaphragmatic hernia (CDH), which was comparable to other studies [10,20]. This condition was found to be a predictor factor of mortality in univariate analysis. Prenatal diagnosis, intrathoracic liver, right sided CDH, a large defect, the presence of associated malformations and prematurity are factors associated with high mortality [21–25]. The lack of adequate clinical stability before surgery with inadequate transfer of high-risk babies from the unit of neonatology to the operative room may be involved in outcomes after CDH repair in our series. The time of surgery and the practice of clinical stability before surgery were evocated in influencing the mortality rate in high risk CDH [25,26]. The optimization of preoperative clinical stability in CDH may decrease the mortality in CDH population. The efficacy of ECMO in reducing mortality is controversial in randomized controlled trials [26–31]. In our country ECMO is not available.

Factors statistically associated with postoperative mortality on univariate analysis were prematurity, low birth weight, the necessity of preoperative intubation, and duration of surgery more than 2 h. Only three factors remained significant after logistic regression, which are low birth weight, duration of surgery >2 h and the necessity of preoperative intubation. A retrospective study looking into mortality after emergency abdominal operations showed that premature infants undergoing operations during the first two months of life had an expectedly high risk of 30-day mortality [28]. Catré et al. found that preterm birth less than 32 weeks of gestational age was an independent factor for severe postoperative complications [20]. Some studies [12,18,29] showed that the age of neonates had an insignificant effect on mortality while others showed that prematurity and low birth weight were demographic factors associated with higher risk of severe postoperative complications [28,32–36]. Collinearity between these two factors may exist. In our study, the univariate analysis showed that prematurity was associated with high mortality. However, in the multivariate analysis, it was not an independent risk factor. The small number of severe premature births in our series may explain this. In our study, birth weight is still an independent factor of mortality after logistic regression.

Neonatal anesthesia and surgery have an effect on the postoperative course, which may influence survival [37,38]. We found after logistic regression that preoperative intubation owing to severe respiratory distress and duration of surgery more than two hours were also independent risk factors of mortality. The presence of associated anomalies was not a significant predictor of mortality, although some anomalies like cardiac ones are known as an important predictor factor in some specific prognosis systems such as Spitz risk grouping [39]. The exact role could not be defined in this study because of the heterogeneity of these anomalies. The type of surgery was a significant predictor of early mortality in some studies [20], whereas in our study it was not an independent factor. This may be because of the heterogeneous number of groups of different surgical procedures.

Our study is one of the few studies conducted in an LIC that investigate predictive factors of mortality in surgical neonates. Some factors are still controversial. The strengths of this study consisted in its database, which included clinical and demographic details of a large sample of neonatal surgical patients from a wide area of the country. It showed the importance of preoperative intubation and the duration of surgery on outcomes. Some interventions may be planned based on these results to help the next LMIC surgeon and neonatologist to face their next neonate. The instauration of prenatal unit and staff may allow better preoperative planning and decisions. The instauration of educational programs for health providers to identify babies with congenital malformations during both the prenatal and post natal period and refer them rapidly to specialized centers would be beneficial. The increase of the number of senior surgeons, anesthetists and neonatologists in public hospitals may offer better perioperative management and better preoperative stabilization and may optimize the duration of surgery. Finally, targeted efforts to prevent severe neonatal infections by increasing the education of health care workers may be proposed.

The limitations of this study were that this study was not an exhaustive research of factors of death after neonatal surgery. The effects of blood transfusion, the preoperative sepsis, the time of day of surgery and other clinical and biological parameters were not reviewed as suggested by previous works [11,12]. Apgar score was only used in the description of patient's characteristics. It was not included in the statistical study because of the missed values. A study of anesthetic parameters like ASA status, hemodynamic parameters, anesthetic drugs and ventilation methods during surgical procedures in developing countries would be interesting to define anesthesia related contribution to death. The data referred to a single center. Further large studies are needed to confirm these findings. Similar studies in similar resource centers in the country should be performed to adequately perform risk adjusted mortality estimates.

Despite the advancement of anesthesia, neonatal care, and neonatal surgery the overall mortality in neonatal surgery is still high. Mortality was found to be particularly associated with low birth weight, respiratory distress, and long surgery. Knowing the independent risk factors of mortality after neonatal surgery may guide interventions to improve results. The recognition of such factors may be used to identify patients who will need more intensive care and allows more accurate prediction of possible results and informed counseling of families.

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References

[1] Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? Lancet. 2003;361(9376):2226–34.
[2] You D, Jones G, Ward law T. Levels and trends in child mortality. UNICEF Bulletin; 2011.

[3] Horbar JD, Carpenter JH, Badger GJ, et al. Mortality and neonatal morbidity among infants 501 to1500 grams from 2000 to 2009. Pediatrics. 2012;129(6):1019–26.
[4] Tomé T, Guimarães H, Bettencourt A, et al. Neonatal morbimortality in very low birth weight in Europe: the Portuguese experience. J Matern Fetal Neonatal Med. 2009;22(Suppl. 3):85–7.
[5] Neto MT, Tavares MN, Serelha M, et al. A vertente cirúrgica de umaunidade de cuidados intensivos neonatais — 25 anos deexperiência. Acta Pediatr Port. 2010;41(6):241–5.
[6] de Bruin L, Pasma W, van der Werff DB, et al. Perioperative hospital mortality at a tertiary paediatric institution. Br J Anaesth. 2015;115:608–15.
[7] Catré D, Lopes MF, Viana JS, et al. Perioperative morbidity and mortality in the first year of life: a systematic review (1997–2012). Rev Bras Anestesiol. 2015;65:384–94.
[8] Ekenze SO, Ajuzieogu OV, Nwomeh BC. Challenges of management and outcome of neonatal surgery in Africa: a systematic review. Pediatr Surg Int. 2016;32:291–9.
[9] Catre D, Lopes MF, Madrigal A, et al. Early mortality after neonatal surgery: analysis of risk factors in an optimized health care system for the surgical newborn. Rev Bras Epidemiol. 2013;16:943–52.
[10] Gangopadhyay AN, Upadhyaya VD, Sharma SP. Neonatal surgery: a ten-year audit from a university hospital. Indian J Pediatr. 2008;75:1025–30.
[11] Badrinath R, Kakembo N, Kisa P, et al. Outcomes and unmet need for neonatal surgery in a resource-limited environment: estimates of global health disparities from Kampala, Uganda. J Pediatr Surg. 2014;49:1825–30.
[12] Manchanda V, Sarin YK, Ramji S. Prognostic factors determining mortality in surgical neonates. J Neonat Surg. 2012;1:3.
[13] Ekenze SO, Ajuzieogu OV, Nwomeh BC. Neonatal surgery in Africa: a systematic review and meta-analysis of challenges of management and outcome. Lancet. 2015;385(Suppl. 2):S35.
[14] Nepogodiev D, Moore R, Biccard B, et al. Prioritizing research for patients requiring surgery in low- and middle-income countries. Br J Surg. 2019;106:e113–20.
[15] Michalski AM, Richardson SD, Browne ML, et al. Sex ratios among infants with birth defects, National Birth Defects Prevention Study, 1997–2009. Am J Med Genet A. 2015;167A(5):1071–81.
[16] Bruckner TA, Karasek D, Yang W, et al. Cohort variation in selection during pregnancy and risk of selected birth defects among males. Epidemiology. 2017;28(4):580–6.
[17] Yagi M, Kohno M, Asagiri K, et al. Twenty-year trends in neonatal surgery based on a nationwide Japanese surveillance program. Pediatr Surg Int. 2015;31:955–62.
[18] Ammar S, Sellami S, Sellami I, et al. Management of esophageal atresia and early predictive factors of mortality and morbidity in a developing country. Dis Esophagus. 2019;1(32(6)).
[19] Ekenze SO, Ibeziako SN, Ezomike UO. Trends in neonatal intestinal obstruction in a developing country, 1996–2005. World J Surg. 2007;31:2405–9 [discussion 2410-1].
[20] Catré D, Lopes MF, Madrigal A, et al. Predictors of major postoperative complications in neonatal surgery. Rev Col Bras Cir. 2013;40:363–9.
[21] Coughlin MA, Werner NL, Gajarski R, et al. Prenatally diagnosed severe CDH: mortality and morbidity remain high. J Pediatr Surg. 2016;51(7):1091–5.
[22] Benachi A, Cordier A-G, Cannie M, et al. Advances in prenatal diagnosis of congenital diaphragmatic hernia. Semin Fetal Neonatal Med. 2014;19(6):331–7.
[23] Tracy ET, Mears SE, Smith PB, et al. Protocolized approach to the management of congenital diaphragmatic hernia: benefits of reducing variability in care. J Pediatr Surg. 2010;45(6):1343–8.
[24] Skari H, Bjornland K, Haugen G, et al. Congenital diaphragmatic hernia: a meta-analysis of mortality factors. J Pediatr Surg. 2009;35(8):1187–97.
[25] Boloker J, Bateman DA, Wung JT, et al. Congenital diaphragmatic hernia in 120 infants treated consecutively with permissive hypercapnea/spontaneous respiration/elective repair. J Pediatr Surg. 2002;37(3):357–66.
[26] Zalla JM, Stoddard GJ, Yoder BA. Improved mortality rate for congenital diaphragmatic hernia in the modern era of management: 15 year experience in a single institution. J Pediatr Surg. 2015;50:524–7.
[27] Ugwu RO, Okoro PE. Pattern, outcome and challenges of neonatal surgical cases in a tertiary teaching hospital. Afr J Paediatr Surg. 2013;10:226–30.
[28] Mugford M, Elbourne D, Field D. Extracorporeal membrane oxygenation for severe respiratory failure in new born infants. Cochrane Database Syst Rev. 2008;16(3):CD001340.
[29] Cairo SB, Tabak BD, Berman L, et al. Mortality after emergency abdominal operations in premature infants. J Pediatr Surg. 2018;53:2105–11.
[30] Snoek KG, Capolupo I, van Rosmalen J, et al. Conventional mechanical ventilation versus high-frequency oscillatory ventilation for congenital diaphragmatic hernia: a randomized clinical trial (the VICI-trial). Ann Surg. 2016;263(5):867–74.
[31] Tsao K, Allison ND, Harting MT, et al. Congenital diaphragmatic hernia in the preterm infant. Surgery. 2010;148(2):404–10.
[32] Lai HS, Lin WH, Chen HA, et al. Successful aparotomy in a 432g extremely low-birth-weight infant with focal intestinal perforations. Int Surg. 2010;95(1):57–9.
[33] Knottenbelt G, Costi D, Stephens P, et al. An audit of anesthetic management and complications of trachea esophageal fistula and esophageal atresia repair. Paediatr Anaesth. 2012;22(3):268–74.
[34] Spitz L. Oesophageal atresia. Orphanet J Rare Dis. 2007;11(2):24.
[35] The Vermont-Oxford Trials Network. Very low birth weight outcomes for 1990. Investigators of the Vermont-Oxford Trials Network Database Project. Pediatrics. 1993;91:540–5.
[36] Does extra corporeal membrane oxygenation improve survival in neonates with congenital diaphragmatic hernia? The Congenital Diaphragmatic Hernia Study Group, J Pediatr Surg. 1999;34:720–4 [discussion 724–5].
[37] McCann ME, Soriano SG. Progress in anesthesia and management of the new born surgical patient. Semin Pediatr Surg. 2014;23:244–8.
[38] Taguchi T. Current progress in neonatal surgery. Surg Today. 2008;38:379–89.
[39] Spitz L, Kiely EM, Morecroft JA, et al. Oesophageal atresia: at-risk groups for the 1990s. J Pediatr Surg. 1994;29:723–5.