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Iatrogenic Vascular Injury: Arteriovenous Fistula in NICU Neonates

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Abstract

Purpose: Invasive treatments have increased the risks of iatrogenic vascular injuries in neonates. Acute complications, such as thrombosis, rupture and pseudoaneurysm, require accurate diagnosis and prompt correction. In arteriovenous fistulas (AVFs) identified in time, some resolve spontaneously whereas others progress and cause major problems; potential growth disturbances and limb discrepancies. The paper is to evaluate the timing of surgery based on considerations of operation risk and expected clinical course in AVF neonates.

Methods: We reviewed the charts of 2776 neonates admitted to the neonatal intensive care unit of the Department of Pediatrics of GMC over the 7-year period (Jan 2010-2017).

Results: Eight (4 males, 4 females) had vascular lesions (0.29%). Mean gestational age was 196.4 days (range, 179-218 days), mean birth weight 985 g (range, 690-1340 g), mean gestational age at operation 352 days (range, 95-679 days), mean weight at operation 1825 g (range, 1230-2700 g), and mean time between diagnosis of fistula and operation 308 days (range, 41-646 days). Definite limb size discrepancy on simple radiographs was identified in 3 patients operated upon more than 1 year after being diagnosed with AVF. In 2 neonates aged between 6 months and 1 year, leg edema was evident and resolved postoperatively. In 3 neonates with simultaneous fistulas in both thighs, surgical correction was preferred for ipsilateral lesions with intense bruit on auscultation. Contralateral small fistulas resolved spontaneously in these 3 neonates within 6 months of initial AVF diagnosis.

Conclusion: Early surgery should not be considered mandatory in all AVF neonates, based on considerations of long-term sequelae, the potential for iatrogenic injury to normal vascular structures and the wide-spectrum of clinical courses. Modulation of operative timing within the 6 months following diagnosis is reasonable as it does not increase risks of permanent impairment or sequela and can avoid unnecessary surgery.

Keywords: Arteriovenous; Neonates; Vascular; Diagnosis

Introduction

The principles of neonate vascular injury management have not been well established. Because of the rarity of vascular trauma in neonates, few centers have been able to accumulate sufficient patient records for meaningful analysis. Furthermore, most large series reported have been based on a decade or more of experience [1,2]. The major causes of vascular injuries in children are iatrogenic, and these injuries account for two thirds of pediatric arterial injuries [3,4]. Rapid advancements in procedures and treatments have remarkably improved the long-term outcomes of extremely low birth weight (ELBW) and low birth weight (LBW) neonates, but have also increased the risks of iatrogenic vascular injuries resulting from catheterization, repeated venipuncture and arterial blood sampling and of associated complications, such as, distal ischemia, necrosis, rupture, pseudoaneurysm and chronic fistula [1-6]. In planning the care of LBW and ELBW neonates, the first rule is to avoid unnecessary harm; if acute vascular lesion is suspected, it should be promptly diagnosed and an aggressive medical or surgical treatment must be initiated [6,7]. But, in cases of chronic arteriovenous fistula, decisions regarding the timing of treatment are problematic, because some resolve spontaneously, whereas others progress to cause to major problems, such as, potential growth disturbances and limb discrepancies [8]. Thus, the timing of surgery for iatrogenic fistula in neonates requires considerations of operation risk and expected clinical course.

Because of the infrequent nature of neonate vascular injury, it has been difficult to design prospective studies to evaluate various methods and results of management. The present study was undertaken to document incidences of vascular injuries and clinical features associated with operative timing and to provide advice regarding appropriate timing by performed a retrospective analysis of corrections performed in neonates admitted to the neonatal intensive care at a single institution of a 7-year period.

Materials and Methods

We reviewed the charts of all neonates admitted to the NICUs (neonatal intensive care units) of the Department of Pediatrics of GMC over a 7-year period from Jan. 2010 to Jan. 2017, during which 2776 neonates were admitted to the neonatal intensive care unit. Admission criteria to NICUs were followed: LBW, ELBW and <2.2 kg Body weight or <6 Apagr score in older neonates. 1883 neonates either had a LBW (41%) or ELBW (21.8%). Arteriovenous fistulas were found in 8 neonates (4 male, 4 female) at the femoral level (0.29%). Neither ischemia nor necroses were encountered. Mean gestational age of these 8 patients was 196.4 days (range, 179 to 218 days), mean birth weight was 985 g (range, 690 to 1340 g), mean gestational age at operation was

352 days (range, 95 to 679 days), and mean weight at operation was 1825 g (range, 1230 to 2700 g). Mean time between diagnosis of fistula and operation was 308 days (range, 41 to 646 days). AVF presented with bruit and thrill at the femoral level. Diagnoses were confirmed by Doppler ultrasonography. Serial postoperative photographs and bone radiographs were reviewed in all cases and used to analyse postoperative results. Physical examination was used to check changes in initial chief complaints postoperatively and Doppler US was used to determine the division between artery and vein, and distal patency after repairing iatrogenic AVF.

Results

Eight neonates (4 male, 4 female) with vascular pathologies (0.29%) either were a LBW or ELBW neonates. During preoperative examinations, definite limb size discrepancy was identified in three neonates with duration of >1 year between diagnosis of arteriovenous fistula and operation (Table 1). Three neonates aged less than 6 months showed only bruit on auscultation without leg swelling, and two neonates aged between 6 months and one year showed bruit and leg swelling, but radiographs showed no obvious limb size discrepancy in these two neonates (Table 1). In three neonates that underwent surgery at less than 6 months after diagnosis of arteriovenous fistula, leg edema was evident but size discrepancy on radiographs was not clear (Table 1). Leg edema resolved postoperatively. Fistula openings in the operation field were at least 3 mm even in 2 kg neonates. Surgical correction was favored for ipsilateral lesions with intense bruit on auscultation and a 3 mm orifice by Doppler sonography in three neonates with simultaneous fistulas in both thighs (Table 1). Surgical correction was deferred for contralateral lesions with weak bruit and no definite edema due to difficulty in localizing and concerns of additional vascular injury. Contralateral small fistulas in 3 neonates resolved spontaneously within 6 months (Table 1). All AVFs were repaired using microsurgical techniques after marking skin incision at the shortest distance from the fistula opening by Doppler sonography. No limb ischemia was observed and no amputation was required (Figure 1).

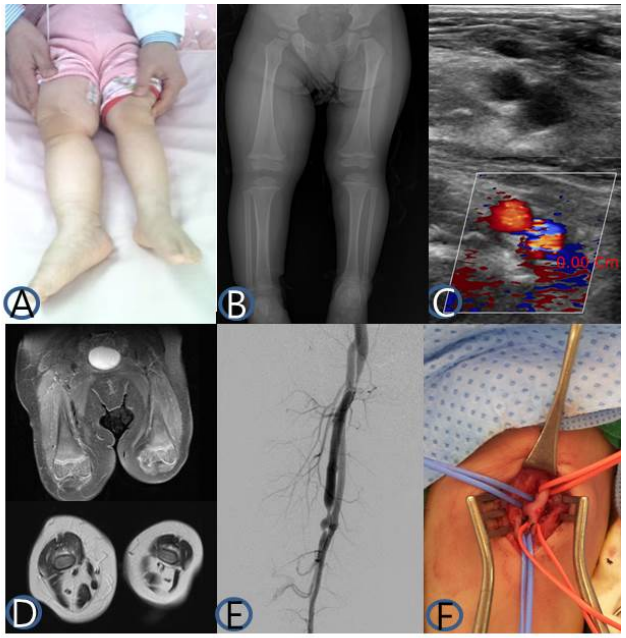

Figure 1: Definite limb discrepancy in a neonate aged 20 months at presentation usually involves the femur or tibia (A) Bone measurements indicated his right leg was 10 mm longer than his left leg (B) Doppler sonography revealed high signal flow between superficial femoral artery and vein (C) MR image showing enlarged volumes of muscle bundles of anterior, medial and posterior fascial compartment muscles (D) Angiography showing arteriovenous communication at the mid-thigh level (E) Surgical exploration revealed 5 mm of communication between the superficial femoral artery and vein (F).

No	Sex	Gestation age (Months +Day)	Birth weight	Apgar score (1/5 min)	Comorbidities	Delivery	Site	NICU (Week +Day)	Age/BW† in surgery (kg)	Diagnosis surgery (Days)	Operation (size) SFA-SFV	Initial symptoms	Postoperative course
1	F	25+5	1000	4/7	RDS*/ROP†/ PDA‡	PSD¶¶	Rt	15+1	1 y 8 m/ 11.7 kg	552	6 mm	Size mismatch	Size mismatch (+) in 3 years
2	M	28+1	1125	2/7	PDA‡/IVH§	PSD¶¶	Lt	3+6	1 y 7 m/ 11.0 kg	561	5 mm	Size mismatch	Size mismatch (+) in 2 yeare
3	F	26+3	980	7/9	NEC	C-SEC**	Rt	16+4	10 m 3 w/4.5 kg	321	5 mm	Thigh: bruit, swelling	Size mismatch (+) in 2 years
4	M	25+4	890	2/7	NEC/ROP†/ PDA‡	C-SEC**	Rt	11+4	8m 4 w/ 8.0kg	268	4 mm	Thigh: bruit, swelling	Size mismatch (-) in 3 years
5	F	30+0	1340	6/8	PDA‡	PSD¶¶	Lt	9+4	1 y 9 m/ 10.3 kg	679	4 mm	Size mismatch	Size mismatch (+) in 3 years
6	M	28+3	930	7/9	RDS*/ Pneumothorax	C-SEC**	Both	14+6	3 m 1 w/2.6 kg	95	3 mm (Rt)	Both thigh: bruit	Lt spontaneous closure in 3 months

7	F	29+0	930	7/8	RDS*/DIC	C-SEC**	Both	12+0	5 m 3 w/ 6.2 kg	174	3 mm (Rt)	Both thigh: bruit	Lt spontaneous closure in 6 months
8	M	31+1	690	5/6	RDS*/PDA‡/ Meconum ileus	C-SEC**	Both	18+0	3 m 2 w/ 2.0 kg	104	3 mm (Rt)	Both thigh: burit	Lt spontaneous closure in 5 months
*RDS: Respiratory Distress Syndrome;‡ROP: Retinopathy of Prematurity; ‡PDA: Patent Ductus Arteriosus; §IVH: Intraventricular Hemorrhage; NEC: Necrotizing Enterocolitis; ¶¶PSD: Preterm Spontaneous Delivery; ** C-SEC: Caesarean Section													

Table 1: Clinical characteristics of LBW and ELBW neonates.

Discussion

Aggressive treatment in NICUs has improved the long-term outcomes of extremely low birth weight (ELBW) and low birth weight (LBW) neonates, but has also increased numbers of iatrogenic vascular injuries caused by multiple puncture or arterial blood sampling [1-5]. The major causes of arterial injuries in LBW and ELBW neonates are iatrogenic, and these injuries account for two thirds of pediatric arterial injuries [6]. Iatrogenic injuries commonly result from catheterization for diagnostic or monitoring purposes, small vessel sizes, multiple diagnostic or therapeutic maneuvers, repeated blood sampling, and parenteral nutrition [3-9].

Because of the rarity of these conditions in infants, few centers have been able to accumulate sufficient numbers of patients for meaningful analysis, and as a result the principles of neonatal vascular complication management have not been well defined. The commonly encountered vascular lesions; limb ischemia, pseudoaneurysms, thromboses, and chronic stage AVF [10,11]. The major sequelae of acute thrombosis in neonates, excluding immediate tissue loss, are growth retardation and in the long-term claudication [12,13]. The incidences of these two complications are difficult to quantify for a variety of reasons. In fact, a literature search failed to identify any study that followed these patients into adult life. Although the diagnostic validities of ultrasonic methods are well documented for adults, these procedures are still under evaluation in pediatric age groups. Results published to date are encouraging, and the diagnostic characteristics of arteriovenous fistulas have been described [3-15].

In principle, acute complications should be promptly in neonates and adults, but surgeons tend to be reluctant about recommending surgical repair in neonates because of small vessel sizes and associated congenital anomalies. When planning the care of LBW and ELBW neonates, the first rule is to avoid unnecessary harm, but that if a vascular lesion is suspected, it should be promptly diagnosed and aggressive medical or surgical treatment initiated [5-7].

However, iatrogenic fistulas in LBW or ELBW neonates, unlike acute lesions, do not cause catastrophes immediately, although even in the absence of immediate concerns, these lesions can cause later problems associated with neonate growth. Timings of better appropriate surgical interventions can be estimated based on assessments of operative and vascular injury risks stemming considerations of body weight, blood vessel structure, and the likelihoods of spontaneous closure and postoperative recovery.

The mechanism responsible for the abnormal limb growth associated with arteriovenous communications has been well investigated, but remains incompletely understood. The increased pressure in the veins in vicinity of the fistula likely produced a certain degree of stasis. This venous stasis has long been recognized as a growth stimulating factor. The growth stimulating effect which is obtained after the formation of the AVF probably can be explained by increased circulation, venous stasis and constant increased temperature in the growth zones [16,17]. The mechanism by which abnormal limb growth occurs in patients with congenital vascular malformations has been investigated. The pathophysiology of abnormal bone growth in patients with a congenital vascular malformation is commonly ascribed to an abnormal blood supply to the growth plate of the long bone in the affected limb. Increased vascularization of the growth plate and hypervascularity of intramedullary small vessels in the presence of high oxygen tension and elevated temperature have been proposed to explain limb overgrowth [18,19]. On the other hand, it was reported in an animal study that ligation of a hind leg vein resulted in leg elongation in 1-month-old dogs. Lower extremity bone overgrowth associated with vascular malformation may be explained by the opening of an existing physiologic arteriovenous fistula compensate for impaired venous outflow in the presence of deep venous aplasia or hypoplasia [20].

Iatrogenic AVF surgical correction should be performed like acute vascular complications, as soon as possible. However, if a neonate weighs less than 2 kg with necrotizing enterocolitis or combined congenital anomalies, it is difficult to localize the pathologic opening using a small incision and this increases the possibility of other vessel damage in narrow and deep field of view. Asymptomatic iatrogenic AVF can evolve and cause permanent impairments and limb mismatch in time. However, it is difficult determining operative timing based on considerations of the possibilities of spontaneous closure and significant symptoms like size mismatch due to small fistula progress in the absence of spontaneous closure.

Conclusion

In our study, it was difficult to detecting progress growth discrepancy in the presence of initial symptoms, such as, swelling, thigh thickness and bruit. But, LBW and ELBW neonates are at greater risk than older neonates of developing iatrogenic chronic AVF in NICU setting. Surgical treatment should be considered if a fistula persists after 6 months of follow-up. The possibility of spontaneous occlusion is minimal when the opening size is 3 mm by ultrasonography even in neonates aged<6 months. Delaying surgical intervention in more than one year is undesirable because leg thickness and discrepancies do not catch up well within 2 to 3 years of follow-up even after surgical correction.

When systemic condition of a patient with a potentially fatal comorbidity (necrotizing enterocolitis with repeated bowel operation, combined congenital heart disease, premature lung condition) becomes unstable, these important issues must be addressed. Surgical intervention in such patients might be reasonably conducted within 6 months of diagnosis, during which time the possibility of spontaneous closure is rare, but weight gain secures a better surgical view.

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