



Treatment of depressed skull fractures with vacuum devices in the neonatal period: A case series

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Abstract

Purpose The management of depressed skull fractures in infants can be either conservative or surgical. This study aimed to examine the outcomes of management with a negative-pressure vacuum device on depressed skull fractures in newborns.

Methods Twenty-eight patients (aged 1–6 days) with simple depressed skull fractures underwent skull elevation using negative-pressure vacuum devices. A protocol for nonsurgical management was adopted for infants with such fractures between 2010 and 2023. All patients were initially evaluated with neurological examination and complementary assessments—hematological and coagulation studies, transfontanel transcranial ultrasound, skull radiography, and computed tomography scanning with three-dimensional reconstruction—according to availability and clinical needs. Gentle (negative) extraction pressure was applied with one of several devices (according to institutional availability) for a maximum duration of 60 s; this was performed as soon as possible after diagnosis, preferably within 72 h. Follow-up data, available in the clinical records, were reported.

Results All patients exhibited satisfactory elevation of the depressed bone without associated injuries, except one patient who presented with an associated cephalohematoma which prevented optimal device coupling to generate sufficient vacuum pressure for correction. Neither neurological deficits nor development of epilepsy was noted; normal neurological assessment and oral alimentation tolerance were confirmed within 24 h post procedure.

Conclusions According to our data, ping-pong skull fracture elevation using the vacuum method is a safe and satisfactory treatment in the neonatal period. Early treatment allows for quick resolution, and in our opinion is the strategy of choice for depressed skull fractures in newborns.

Keywords Ping-pong fracture · Vacuum extractor · Neonates · Pediatric neurosurgery

Introduction

Depressed skull fractures in newborns, also known as “ping-pong,” “pond,” “derby hat,” or “celluloid ball-like” fractures, are considered to be the equivalent of “green-stick” fractures of the skull [1]. They are a rare condition presenting during the neonatal period, presenting in about 4–10 cases per 10,000 live births. These fractures are thought to be caused by compressive forces on the head against pelvic prominences during labor, and in older neonates and infants, they

have been reported as a consequence of head trauma, representing up to 23% of all cranial fractures [2].

The most common clinical presentation of depressed skull fractures in neonates is a visible skull deformity after birth. One hypothesis states that the bone may be deformed against either the pubic symphysis or coccyx and sacrum while the head moves through the birth canal [3]. In 1974, Tan [4] treated two newborn infants with depressed skull fractures, describing their development in utero and in the absence of obvious trauma; this was evidenced by the presence of fractures after easy deliveries, with no signs of trauma in the overlying scalp. In 1979, Saunders et al. proposed that the origin of these depressions could be the result of several factors, including the pressure applied by the obstetrician’s hand, and extreme skull molding against the pelvic osseous prominences of the mother during passage through the birth

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canal [5, 6]. Other authors believe that neonatal depressed skull fractures may occur secondary to the pressure applied by the fingers or wrists of the fetus over the surface of the cranium in utero [7].

The standard treatment for this entity has not yet been established in the neonatal population [7–10], with surgical strategies and conservative management used according to the clinical context and physician's discretion. Several surgical techniques are described for the management of depressed skull fractures; these include elevation of the fracture with a periosteal elevator through a burr hole (or, if feasible, through the nearest skull suture in neonates and infants with patent sutures, to avoid the creation of new burr holes) at the margins of the fracture [11], insertion of a percutaneous screw or hook through the center of the fracture to pull upwards and elevate the flap [12], or performing a circumferential craniotomy around the fracture to remodel and reinsert the bone flap [1]. These interventions are based on data of older children and adults, suggesting that in depressions deeper than 1 cm, there is an increased risk of dural and cortical lacerations, and these have been reported to be risk factors for the development of posttraumatic epilepsy, although these critical dimensions are less well known in the neonatal population [12]. Noninvasive reduction by applying digital pressure at the margins of the fracture has also been reported; this avoids further intervention, as the conservative approach with observation has been described with variable success rates [13].

The use of negative-pressure suction devices as a noninvasive procedure—including obstetrical vacuum extractors, breast pumps, or even a pediatric oxygen mask attached to a syringe to create negative pressure—has been reported in the past [2, 9, 14, 15], providing a nonsurgical and minimally invasive technique for management in some cases. In 1970, Schragar reported the first case of a depressed skull fracture completely elevated by a vacuum device in a newborn female (4 kg), wherein gentle suction was used over the depressed area for 15 min [16]. Two years later, in 1972, Van Enk used a Malström vacuum hand pump for this purpose, successfully maintaining sustained suction for 4 min without scalp damage [17]. Since then, several successful cases have been reported, with a recent systematic review of the literature suggesting that the results of elevation using a vacuum device are comparable to those obtained with surgical management, particularly in the case of simple depressed skull fractures [13].

Some contraindications for the noninvasive management of depressed skull fractures include cerebral tissue compression by fractured bone pieces, neurological deficit or other signs indicative of epidural or subdural hematoma, suspected rise in intracranial pressure, cerebrospinal fluid subgaleal collection, and failure to restore normal skull convexity with noninvasive techniques [18]. Nevertheless, owing to

the rarity of this entity, there is a scarcity of data regarding definite indications and contraindications for this technique.

Here we report our experience in managing neonatal depressed (or ping-pong) skull fractures using a vacuum extractor device (according to institutional availability) in a series of 28 patients treated by our group over 13 years. We aimed to examine the results of timely elevation on ping-pong skull fractures in neonates using a negative-pressure vacuum extractor. A specific protocol for nonsurgical management was adopted at our institution for all newborns with these fractures.

Methods

This retrospective study was performed in the Division of Pediatric Neurosurgery (Department of Neurology and Neurosurgery, Universidade Federal de São Paulo, São Paulo, SP, Brazil), and hospitals from the Santa Joana Group between 2010 and 2023. All neonates and infants with depressed skull fractures treated using vacuum (negative-pressure) devices were included in the present report. Patients were thoroughly evaluated with a detailed neurological assessment and select complementary studies, including hematological and coagulation studies, transfontanel transcranial ultrasound, skull X-ray, and skull computed tomography (CT) with three-dimensional (3D) reconstruction (in selected cases). Patients with evidence of neurological focalization and/or radiological evidence of compressive effect of hematomas on the underlying brain parenchyma that required surgical drainage were excluded of this approach, being treated in standard surgical fashion. The procedure was explained to the parents, and informed consent was obtained for all patients for the procedure, according to standard care.

Treatment consisted of fracture elevation using transcutaneous vacuum negative-pressure traction; the choice of device between a vacuum obstetrical extractor or a neonatal reanimation mask coupled with a 50-mL syringe was made according to institutional availability. The sedation method was selected according to the preference of the anesthesiologist. The maximum extraction pressure applied, in cases where it could be measured, was 10 BAE (pressure of 0.3–0.8 kg/cm²), sustained for approximately 20–40 s; in the cases in which the extracting pressure could not be measured, gentle but sustained force to reduce the depressed fracture was exerted for the same period of time. Up to three attempts of reduction were allowed before considering switching to an open approach, to avoid significant soft tissue injury. The prompt elevation procedure was performed as quickly as possible after admission, as after 72 h, the defect has been described as more difficult to elevate¹⁹.

Complete reduction of the fracture was defined when the normal skull convexity was reinstated after the intervention (elevation of approximately > 80% of the previous depression); partial resolution was defined in cases with a reduction between 50 and 70%; and nonresolution was defined in cases with < 50% reduction, as measured in the post-procedure skull CT and clinical examination. An outcome was considered good if discharge was achieved within 48 h of clinical observation, without neurological or significant soft tissue injuries (scalp ecchymoses or hematoma). Complementary post-procedure imaging studies, such as skull CT with 3D reconstruction, skull radiography with anterior–posterior and lateral projections, or brain ultrasonography, were performed within 24 h after the procedure to dismiss associated injuries or complications and to evaluate the fracture reduction.

After discharge, the patients were evaluated 3 weeks, 3 months, and 6 months after the procedure. The follow-up

process aimed to assess neurological deficits or extracranial complications (cephalohematoma or hemorrhage).

Results

In 27 of the 28 patients, satisfactory elevation of the bone flap was achieved without associated injuries. In one patient without resolution of the fracture (case number 2), a cephalohematoma was identified above the depressed area; even after drainage, coupling of the vacuum device was unable to generate enough pressure for correction. In concordance with other reported series, most depressed skull fractures were parietal ($N=11$), frontal ($N=6$), or temporal ($N=6$); no neurological or focal deficits were observed.

We do not routinely use post-procedural brain CT scans. In a few cases that underwent CT scan, neither subdural nor subarachnoid hemorrhage was encountered in the

Table 1 Summary of clinical cases and vacuum extraction with “ping-pong” depressed skull fractures

No.	Sex	Age (days)	Gest. age (weeks)	Birth type	Localization	Cephalohematoma	Resolution
1	F	4	32	V	(R) Frontotemporal	No	Co
2	M	5	34	V	(L) Frontotemporal	Yes	NR
3	F	2	35	C	(R) Parietotemporal	No	Co
4	M	3	36	C	(L) Parietotemporal	No	Co
5	F	2	38	C	(R) Frontal	No	Co
6	F	2	40	C	(L) Frontal	No	Co
7	M	3	32	C	(R) Frontal	No	Co
8	M	3	33	V	(L) Occipitotemporal	No	Co
9	F	2	36	C	(R) Temporal	No	Co
10	M	2	38	C	(L) Temporal	No	Co
11	F	1	37	C	(R) Temporal	No	Co
12	M	2	37	C	(L) Temporal	No	Co
13	M	2	33	C	(R) Frontal	No	Co
14	M	3	36	C	(L) Parietal	No	Co
15	F	2	37	C	(L) Parietal	No	Co
16	M	2	34	C	(R) Parietal	Yes	Co
17	M	2	39	C	(L) Parietal	No	Co
18	M	3	37	C	(R) Parietal	No	Co
19	F	1	37	V	(L) Parietal	No	Co
20	M	1	37	V	(R) Parietal	No	Co
21	M	2	38	C	(L) Frontal	No	Co
22	F	3	37	V	(R) Temporal	No	Co
23	F	1	39	C	(R) Parietal	No	Co
24	M	1	38	C	(L) Frontal	No	Co
25	M	3	39	V	(R) Parietal	No	Co
26	F	1	39	C	(R) Parietal	No	Co
27	F	6	35	C	(L) Parietal	No	Co
28	F	6	38	C	(L) Temporal	No	Co

C cesarean section, Co complete resolution, F feminine, Gest. gestational, L left, M masculine, No. number, NR nonresolution, R right, V vaginal delivery

post-procedural tests. We used transfontanelar ultrasound as a postoperative image tool to screen for any intracranial abnormality. All patients were discharged from the neurosurgical ward within 48 h after the procedure, without any neurological deterioration during their hospital stay. None of our patients presented seizures after the procedure, or new neurological deficits in the follow-up period. Further data is available for revision at Table 1. In Fig. 1, an illustrative case is shown with pre-procedure and post-procedure images, showing the extent of reduction achieved with the vacuum device technique in one patient of this series. In Fig. 2, more details about the vacuum device's coupling to the head are shown.

A favorable clinical evolution was confirmed in all cases, with normal neurological assessment and oral tolerance confirmed within 24 h after the procedure, in concordance with the Pediatrics Department control and follow-up. In the adjunct Video 1, one case's procedure is shown to illustrate

the technique used by our group in these cases. No further neurological deterioration or complications were encountered during the 6-month follow-up period.

Discussion

Ping-pong or depressed skull fractures have been previously described in the neonatal and infantile population [1, 5, 15]. The special elastic properties of the immature skull bone in these age groups, such as its softness and thinness compared with mature skull bone, explain the frequency of this type of fracture and its unique presentation in neonates and infants. The mechanism of trauma in these patients tends to be low energy, as the soft skull bone in this group of patients can be easily deformed [4, 10]. Differential diagnoses in this context must, therefore, include scurvy, osteogenesis imperfecta, Menkes disease, and vitamin D deficiency [11].

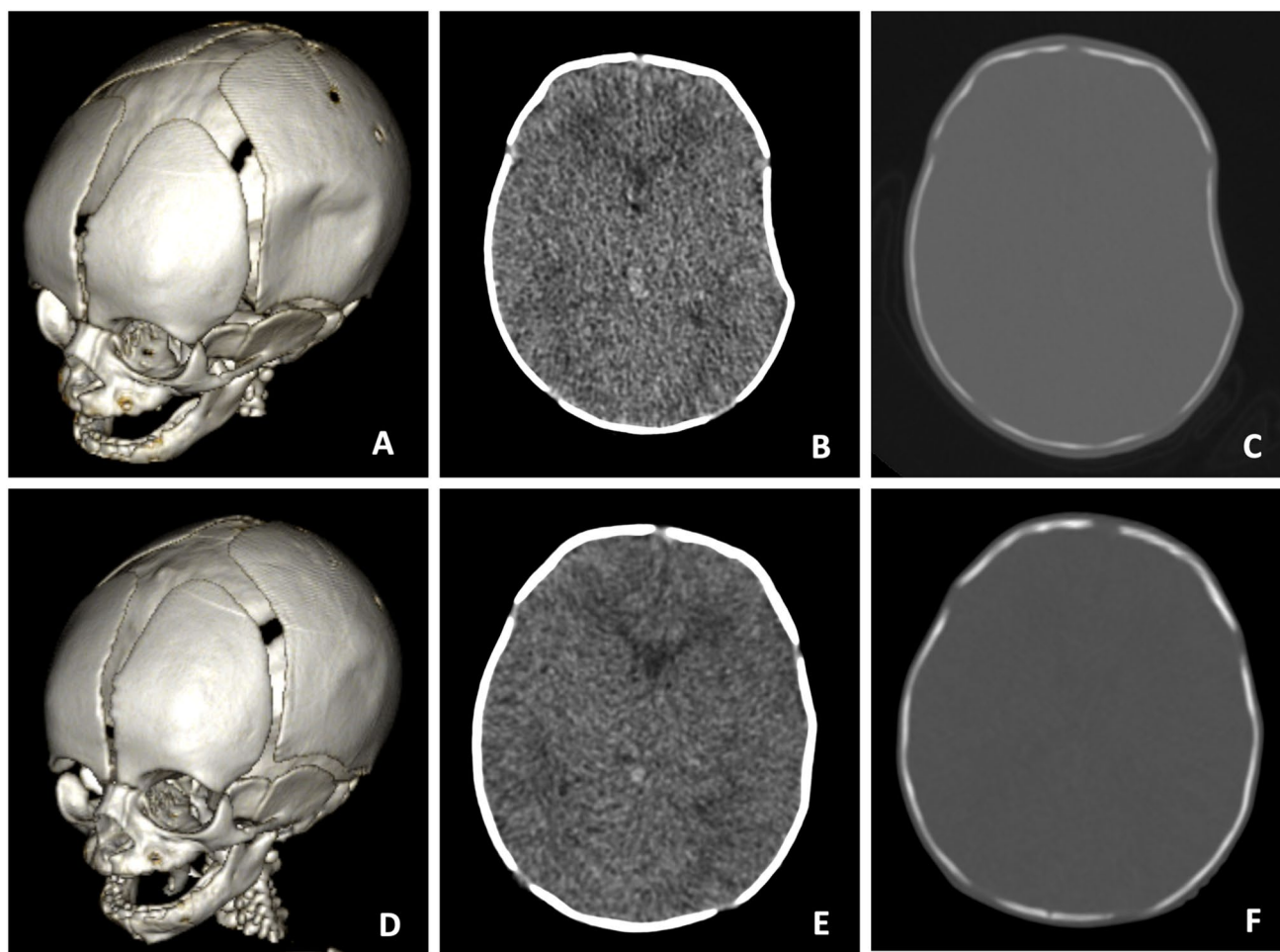


Fig. 1 A 6-day-old female neonate presented with a depressed left temporal fracture and underwent fracture reduction with a negative-pressure vacuum device, with a complete resolution of the depression. Panels A–C show CT 3D reconstruction, axial skull CT with

brain window, and axial skull CT with bone window of the bony depression before its reduction. Panels D–F show CT 3D reconstruction of the skull, axial skull CT with brain window, and axial skull CT with bone window after fracture reduction procedure

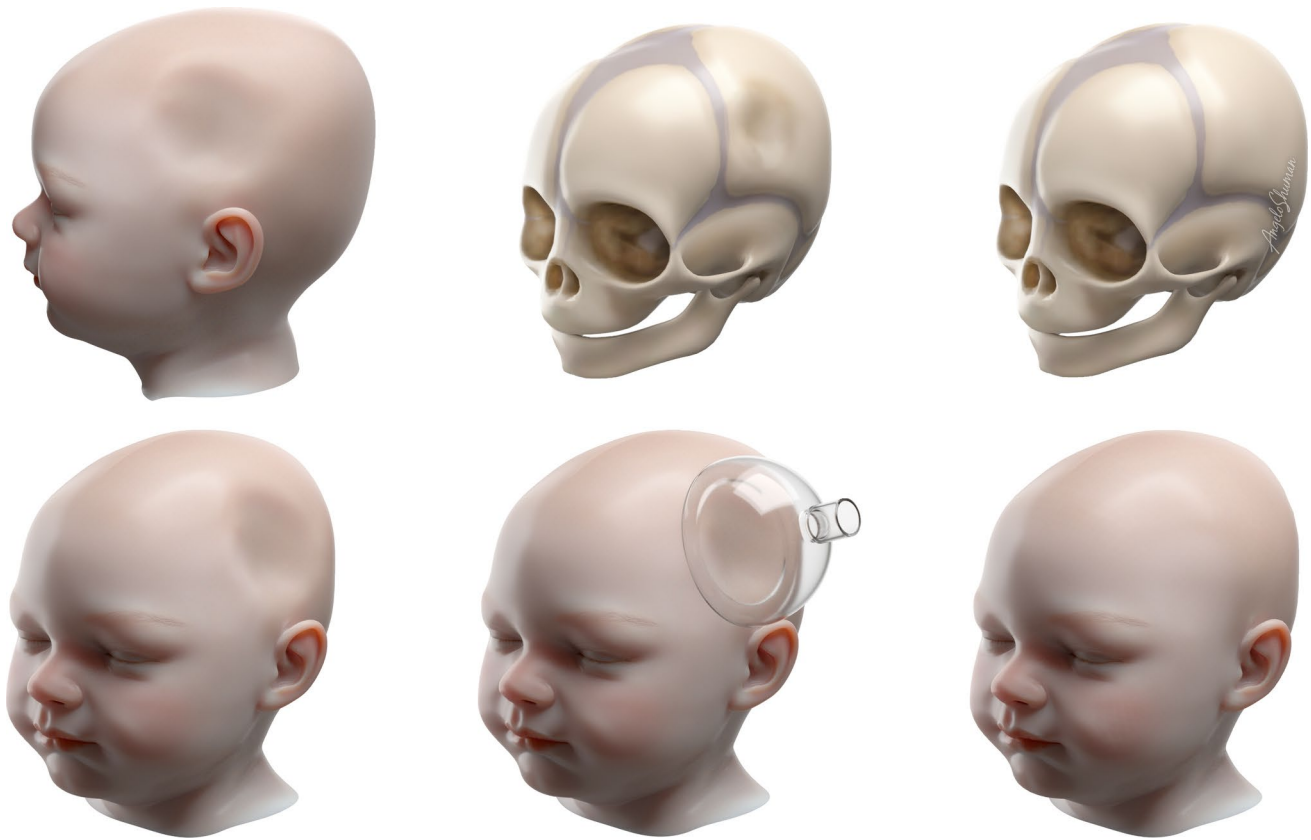


Fig. 2 Schematic illustration showing the attachment of the vacuum device cup to the scalp overlying the depressed fracture and its subsequent reduction with the negative-pressure technique with a vacuum device, as well as an illustration of the effect on 3D reconstructed bone

A larger published series by Hung et al. [21] reported the outcomes of 14 patients with depressed skull fractures treated using the vacuum extraction technique, with a success rate of 92.9% (13/14 cases). Nevertheless, only five of these cases involved newborn subjects, and complications included scalp hematoma. In a recent case-based systematic literature review published by Ballestero and De Oliveira (including eight research papers) [2], 35 children who underwent skull fracture reduction with a negative-pressure extractor were identified. Among their results, there was no clear age limit for the intervention (with the oldest reported patient being 17 years old), with a success rate of > 97% and only one reported case of cephalohematoma. In another case series published by Arocho-Quinones et al. in 2020 [20], successful cranial depressed fracture elevation was reported in seven of nine cases—of which four were neonates and seven were infants—without any major complications associated with the procedure.

Although minimally invasive surgical techniques, such as fracture elevation with no burr hole through the coronal suture [11], or screw techniques for fracture reduction [12] have been previously described, both require general anesthesia for management, despite minimal operative bleeding and no osseous

loss in these patients. In our series, as well as in other reports, elevation with a vacuum extractor could be performed under sedation without intubation according to the anesthesiologist's evaluation and patient condition [20], thereby minimizing the invasiveness of the intervention and associated risks. As for imaging techniques, CT scans with 3D reconstruction have been promoted as an important tool, because they provide more information than plain radiographs [19]. We believe that the increased exposure to ionizing radiation (with incremental risk for the neonatal population) must be taken into account in order to avoid unnecessary imaging, although CT scanning with 3D reconstruction provides important information in the planning and follow-up of complex cases, and is widely used nowadays.

Conservative observational management may be an option for neonates with depressed fractures < 5 mm in depth, as their spontaneous resolution has been previously described, albeit in a period not inferior to 4–6 months [13, 14, 18]. In this sense, we found that the anxiety to which the patient's family is subjected, as well as the theoretical risks associated with parenchymal brain compression, is a sufficient factor to favor the intervention of these fractures; in our opinion, the least invasive procedure should be preferred for this kind of patient. Additionally, we believe that

depressed skull fractures in newborns and infants should be treated as soon as possible to avoid brain compression, local inflammation, the possible subsequent development of an epileptogenic focus, and therapeutic failure brought on by prolonged evolution [7]. Furthermore, the social effect of the noninvasive procedure in neonates in itself prevents unnecessary parental anxiety and stress, and avoids the consequent interruption of breastfeeding [15].

We regard the time of fracture evolution as an important variable in the successful management of depressed skull fractures with vacuum devices, which is supported both by the findings in our study, as well as previous literature reports [20]. In accordance with prior literature publications, we consider that there are several factors that affect the capacity to opportunely treat these fractures in the neonatal population using this modality: the newborn's prior evaluation, with absence of neurological complications and indications for surgery; the patient's age; and the fracture evolution time [21]. In our case series, all newborn depressed skull fractures cases with an evolution time under 72 h exhibited complete resolution of the fracture with this technique, without any associated complications detected. Performing the treatment in the period before fracture consolidation seems to allow fracture reduction when using this noninvasive technique. Despite this being the most accepted theory, some reported successful cases extend beyond this time frame [14, 20]; still, most of the reported successful cases managed with vacuum devices reported in literature were treated within 72 h of diagnosis [13]. It is worth noting that the presence of cephalohematoma was the main predictor of failure found in our series for the vacuum device elevation of depressed skull fractures in the neonatal population.

The main limitation of our study is the absence of control cases; as we did not treat depressed skull fractures conservatively, we could not compare the two cohorts. Due the number of patients and the narrow age group included, our results should be taken into consideration for the neonatal population, as more data is required to generalize this results in older populations.

Conclusions

This case series adds to the body of evidence supporting the treatment of depressed skull fractures using vacuum devices, which has been shown to be a safe, fast, effective, and feasible technique for elevating these skull fractures in the neonatal population. Our literature review found similar results regarding the effectiveness and safety of this intervention in these patients. Furthermore, we believe that early treatment of this entity allows quick resolution, avoids surgical exposure, decreases hospital stay, and

prevents the social effect of family stress related to more invasive procedures (such as surgery and anesthetic procedures), or the restlessness associated with the delay in visible results when conservative management is pursued.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00381-023-06261-z>.

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Authors' contributions Mauricio Puch: conceptualization, writing of the draft, data acquisition. María Carolina Portela Fernández: data acquisition, writing of the draft, review, and editing. Marcos Devanir Silva da Costa: conceptualization, data acquisition, review and editing. Patricia Alessandra Dastoli: review and editing. Sergio Cavalheiro: supervision, review, and editing.

Availability of data and material Not applicable.

Declarations

Ethics approval and consent to participate The study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo, São Paulo, Brazil. Informed consent was obtained from all the guardians.

Consent for publication Informed consent was obtained from the guardians for publication.

Conflict of interest The authors declare no conflict of interest.

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