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Management of growing skull fracture using cadaveric bone graft

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Abstract
Growing skull fracture (GSF), a delayed cranio-cerebral complication resulting from linear skull fracture with dural tear. Damaging effects on the developing skull and brain are significant. Dural tear results in leptomeningeal cyst formation, which if left untreated progressively induces local resorption of skull bone (GSF) and secondary damage of the developing brain.
Various materials are available for cranioplasty. It is directed at protecting dura and brain. Cadaveric bone is the most biological, physiologically suitable material available. It may have immediate effect on stopping skull-bone resorption.
In our knowledge this is the one of the initial cases of reconstructive-cranioplasty using cadaveric skull bone in GSF. Its effects followed up with 10-years clinical & radiological studies.
It is used with the intention of studying 1) host's ability to regenerate skull bone after cadaveric bone grafting and 2) short term & long term effects of bone grafting in paediatric age group.

Keywords: Paediatric head injury, growing skull fracture, cadaveric skull-bone and reconstructive-cranioplasty

Introduction

Cranioplasty and trephination dates back to 7000BC, Hippocrates & Galen era [1]. Thereafter a long gap reconstruction was reported only in the 16th century by Fallopius. He used gold plates for cranioplasty [1]. Canine bone graft first used by Meekeren in 1668 [1]. Autografts and alternative metals were used in 20th century. Poly Methyl Metha Acrylate (PMMA) is commonly used acrylate for cranioplasty and was introduced in 1940 [1].

It is estimated that in 75% of all linear- skull fractures [2] children are younger than 3-years of age [3]

Growing skull fracture, also known as "post-traumatic leptomeningeal cyst" or "craniocerebral erosion" was described first by Howship in 1816. [4]

The incidence of GSF is 0.05% to 1.6% of skull fracture-cases [5 6] Pathogenesis is entrapping of the dural, arachnoid membranes and brain tissue within the fracture margins with growing brain dimensions in the early age group. [7 8]

During first 2 years of age, the skull bone is thin & more flexible, but thickly adherent to the underlying dura, as a result gets torn along with the fracture [9]. Neurological deficit is secondarily due to the brain tissue entrapment. It also results in encephalomalacia and ventricular pulling effect towards the site of growing skull-fracture.

Surgical management in a paediatric developing brain involves 1) early repair of the dural defect and leptomeningeal cyst and 2) reconstructive -cranioplasty. Delay could result in more brain damage.

Repair of dural defect with pericranium gives good tissue compatibility [10 11 12]. On the same principle, cadaveric bone was used for reconstruction of the fracture-skull defect. Cadaveric bones have been used for other cranioplasty but for the first time used for paediatric head injury resulting in GSF. The cadaveric bone graft was obtained from a Cadaveric Bone Bank.

Clinical presentation

Two year four months old female child presented in June 2004 with a 5 x 6 cm large soft pulsatile swelling in her right parietal area of the head. Mother noticed that the scalp swelling had grown in size over the last 7- 8 months and now there was a skull defect underneath the swelling. The swelling and the skull defect both had grown in size over the last one year.

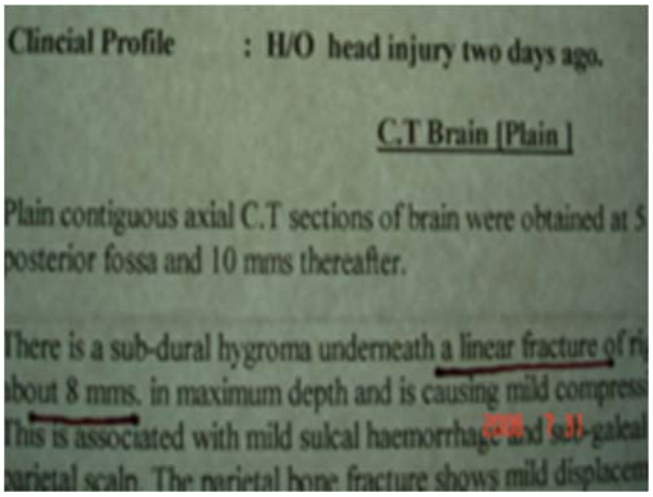
She frequently visited her doctor but did not get any definitive treatment. No brain computerised tomography (CT) scanning was done during that period.

Past history was significant. In July 2002, child at the age of four months had a minor fall without any abrasion, contusion or laceration on the scalp. Parents had forgotten the trauma as it was reported very negligible. However, at that time brain CT plain studies were done. Reports of that brain- CT showed 8 millimetre long linear fracture in the right parietal bone. There was no brain parenchymal injury as per the reports. (Figure 1).

Preoperative Skull- X-rays in June 2005 (Figure 2A) and Brain CT in January 2004 (Figure 2B) showed large skull defect at that site of earlier linear fracture. Fracture was no more linear, instead there was a large bony defect and margins were

irregular. CT brain showed 1) pulling of posterior horn of left lateral ventricle towards growing fracture site, 2) well defined herniation of brain tissue through the bone defect 3) regional encephalomalacia and 4) bony lytic deformity in the skull. There was no history of fever, no seizures no neurological clinical deficit. These findings were suggestive of a growing skull fracture (GSF).

The GSF was in its 3rd stage. Brain cortical - tissue was seen entrapped in the dural defect. Posterior horn of the right lateral ventricle seen pulled towards the GSF. Bony-defect was very large and was the result of bone resorption caused by the growing lepto-meningeal cyst. (Figure 2B)

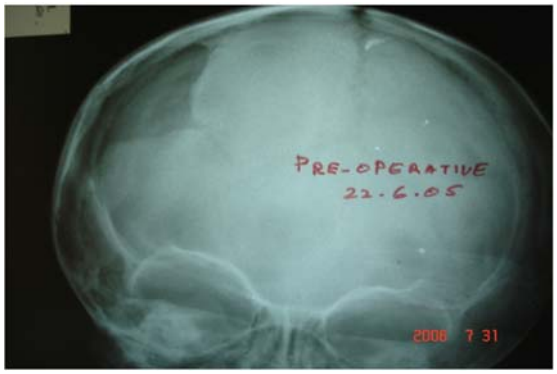

Clincial Profile : H/O head injury two days ago.

C.T Brain [Plain]

Plain contiguous axial C.T sections of brain were obtained at 5
posterior fossa and 10 mms thereafter.

There is a sub-dural hygroma underneath a linear fracture of ri
about 8 mms. in maximum depth and is causing mild compress
This is associated with mild sulcal haemorrhage and sub-galeal
parietal scalp. The parietal bone fracture shows mild displacem

Fig 1: Printed report is of the CT brain-scan done when baby was 4months of age -reporting the linear fracture.



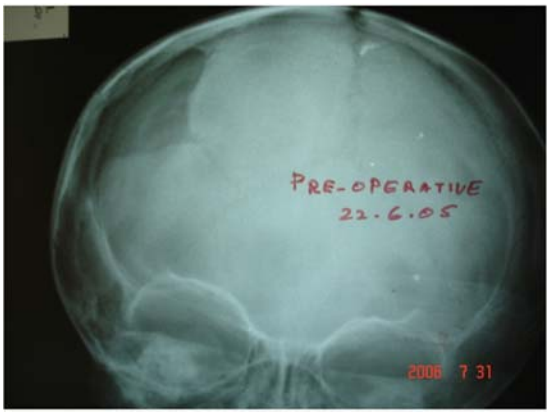
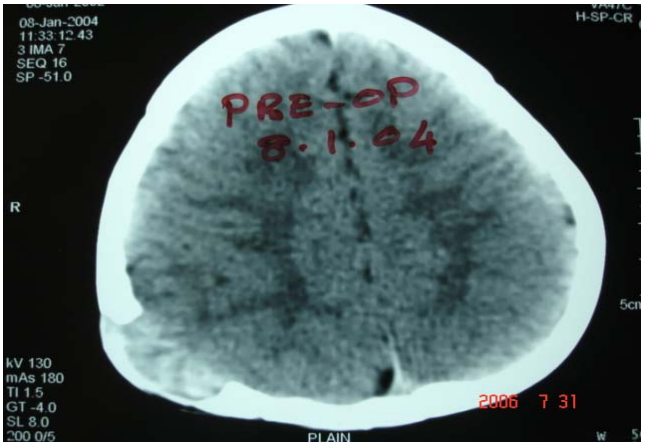


Fig 2A: Preoperative AP Skull radiograph showing a well-defined lucency over the right parietal region



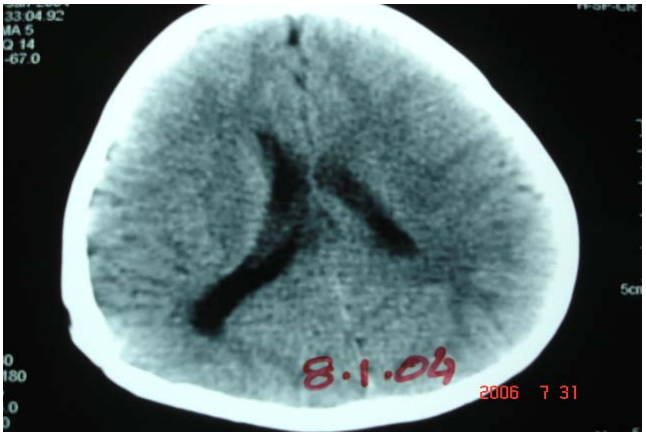


Fig 2B: Preoperative CT scan showing Growing Skull Fracture (GSF): bony-defect in this case was larger than the dural defect. Large leto-meningeal cyst, cortical tissue entrapment

Operation 2004

1. Reconstructive-cranioplasty performed under general anaesthesia. [1] Patients' skull bone's fractured margins freshend-up again with bony-nibbler.
2. 10mm burr holes drilled on the host's skull to produce bone dust. [2] The small dural defect repaired using scalp aponeurotic-fascia (Figure 4).

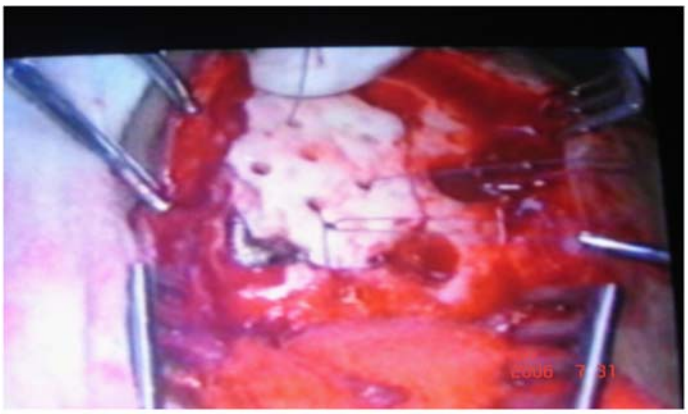


Fig 4: Intra-operative: Bony defect well positioned and reconstructed, cadaveric bone

Cadaveric Bone: Thin cadaveric skull bone obtained from bone bank (Figure 3). Selected bone drilled with multiple small

holes separated at 1 to 1½ centimetre distance from each other. It was cleaned with 10% sodium trisulphate solution for 2-weeks, thereafter manually cleaned of all its blood and periosteal tissues. It was dried at 60F degrees temperature for 48 hours and packed under aseptic conditions in a completely dried format and sterilised in Ethylene Oxide sterilisation (EtO) unit. It was brought to the operation theatre in completely aseptic condition.

Cadaveric graft soaked in betadine diluted with sterile normal saline on the operation table. Bone flap was cut, shaped and its margins were bevelled so that it could oppose well on to patients' skull bone. It is important to bring in edge to edge contact and freshening-up edges in the bevelled format, so that bones oppose on to each other. The bone-dust (particles) later on used for filling holes on the cadaveric bone. Cadaveric skull bone closed the large-skull-defect and fixed with Vikryl-sutures. Its use effectively shortened the operation time. Gelfoam, Surgicel, bone-wax not used to avoid interference with osteoblastic activity of the progenitor cells. Reconstruceted cranioplasty was well covered with periosteum and scalp closed with silk sutures. Gen tamycin 250mg/iv, and Ceftriaxone 250 mg/iv intra & post operatively given for 7 days.

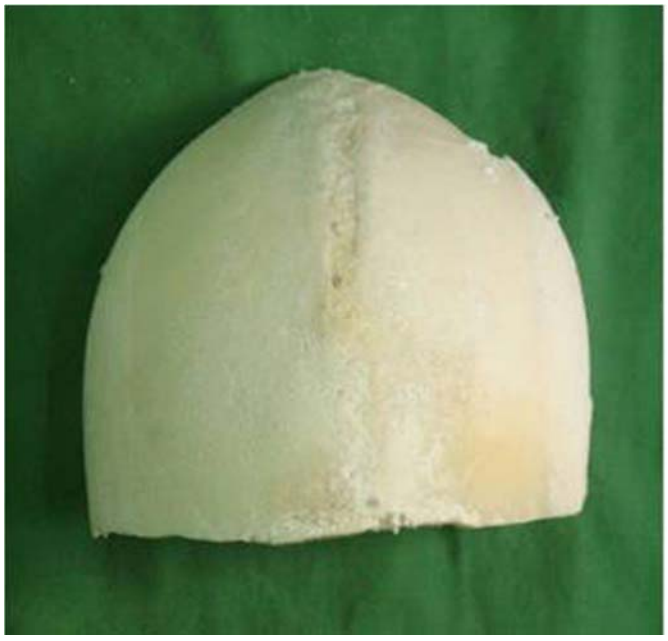


Fig 3: Non-gazetted, ETO- sterilised, prosthetic graft stored at room temperature

Results

Post-operative: Dural closure effectively prevented further leakage of cerebrospinal fluid (CSF). The cranioplasty immediately stopped bony resorption-process that was induced by the cyst. Reconstruction gave immediate & long standing safety to the underlying brain tissue. It prevented further entrapment of the cortical tissue and leakage of CSF. There were no effects like fever and rash observed during the early, mid & late post-operative stages indicating any immunological response of local or systemic type. The cadaveric bone-graft was well accepted. She was discharged on 8th post operative day after antibiotic cover. She was closely followed up over the next 10 years.

Follow up: There were no untoward local or systemic immunological effects observed during that period. No long term antibiotics were given. Radiological studies were done after 1year (Figure 5A and 5B) New bone growth formation noted along the grafted bone and no deficiency nor excess formation seen. Grafted bone did not demineralise over the following 10 years.

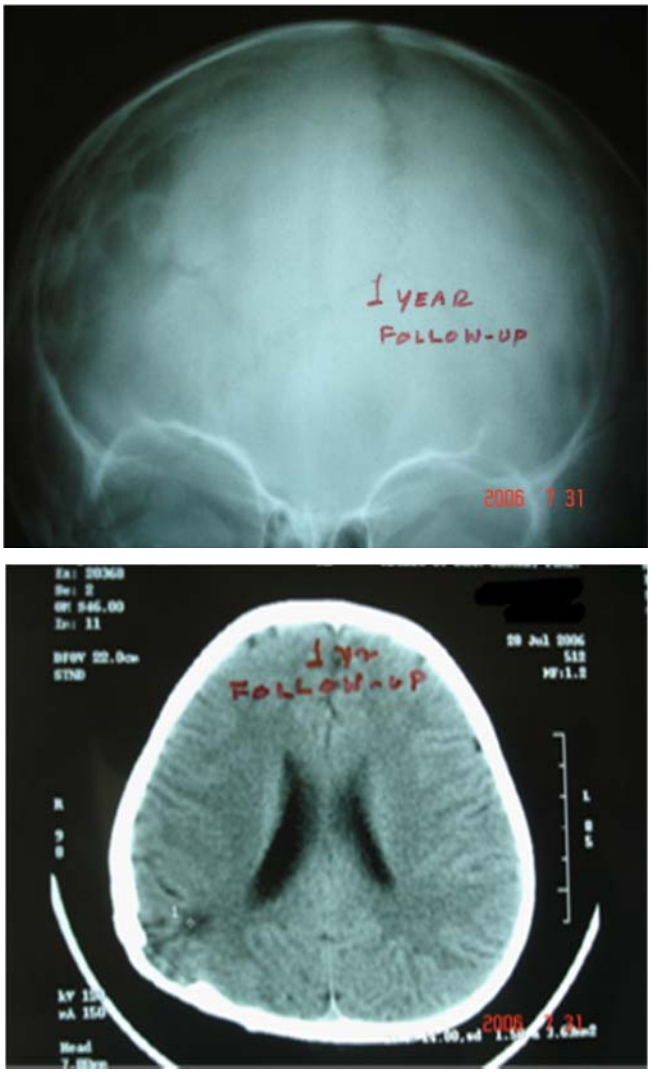


Fig 5: One year post-operative follow up A) radiograph and B) CT scan showing significant obliteration of the right parietal defect

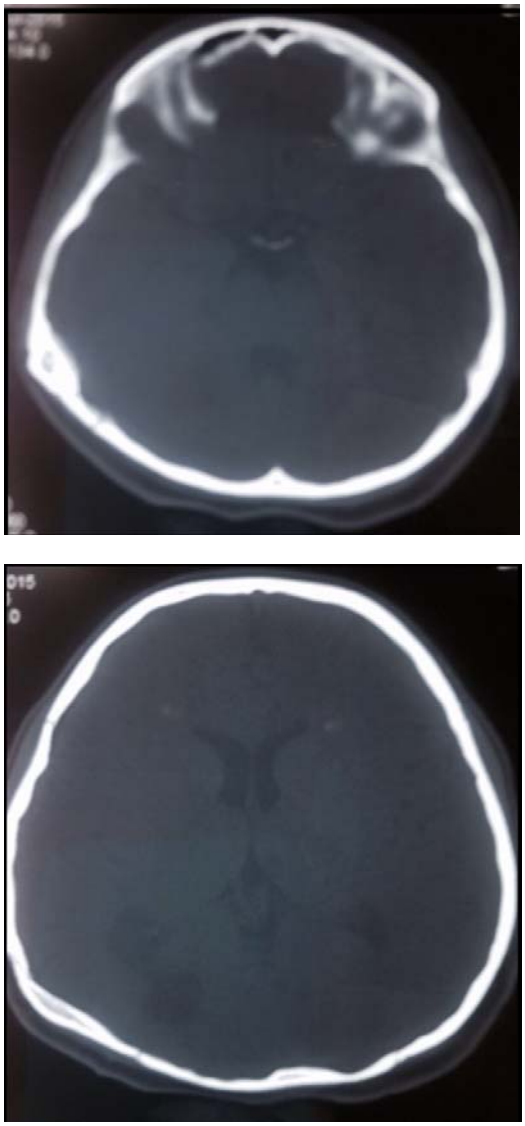


Fig 6: Follow-up- A) Clinical-photograph after 10years B) Plain CT with bone window showing Good - osteosynthesis, C) Plain CT soft tissue window showing normal brain & ventricles bilaterally.

Cadaveric grafted bone over the last 10 years seen well accepted in the paediatric patient. CT brain with bone window at 10 years showed good fusion (new bone formation); at the grafted site. (Figure 6 B, C).

Brain cortex between the repaired dura and the lateral ventricle were within normal limits. Graft induced new formation all along the membranous bone. Biologic bone-material stabilised the growing fracture; helped attain perfect reproduction of the defect with normal head counter.

Discusion

Paediatric skull bone is more membranous-type and differs from the adult cancellous type. Bone resorption is a local osteolytic process. Neurological brain loss in growing developing child is astounding.

The bone morphogenic protein (BMP) is a low molecular weight glycoprotein & induces bone formation through its progenitor cells. Induction of ectopic bone formation with acid treated-demineralized bone matrix in the muscle was successfully demonstrated by Marshall Urist in 1965 [13]. These differentiate in to chondrocytes which calcify with vascular invasion. The terminal stage is bone remodelling and marrow formation [14].

BMP obtained from the bovine bones also has shown similar activity. Clinical fusion depends on the good volume of grafted bone materials [15]. Recombinant human BMP (rh BMP) does not cause host versus graft immune response and is free of infectious agents and contaminants. [16] Safety and modality of bone growth over the exposed decompressed dura was established using rh BMP [17 18]. The cost of single BMP application for clinical usage is more than $5000 [19].

Conclusion

Cadaveric graft in sufficient quantity is an effective and safe method in paediatric head injuries. GSF needs early surgical reconstructive cranioplasty. Cost factor is very low and cadaveric bone seen as more biological material as compared to the acrylates, titanium plates.

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