Decision Making in Frontobasal Injuries

S.Zeme, G.Gerbino°, F.Benech*, C.A.Pagni*, F.Roccia°, C.Caldarelli°, S.Berrone°*
*Department of Neurosciences, Neurosurgical Division, University of Turin (Italy)
°Maxillofacial Surgery Division, University of Turin (Italy)

Summary

We analyzed a series of 142 patients suffering a frontobasal injury severe enough to produce a frontobasal fracture. High velocity trauma was the cause of injury in 95 patients (67%). A frontobasal fracture was the only noticeable lesion in 27 cases (19%). It was associated with maxillo-facial fractures in 79 patients (56%), with intracranial lesions in 47 (33%), with intraorbital lesions in 14 (10%), and with politrauma in 10 (7%).
In 107 patients (75%) surgical treatment was required either to repair the craniofacial fractures and/or the intracranial and intraorbital lesions. In this group 62 patients (58%) were operated on by the maxillofacial surgeon only, 45 (42%) by a combined maxillofacial and neurosurgical team. 20 patients (19%) required an emergency operation because of an expanding intracranial mass or a craniocerebral wound. In 50 cases (47%) the operation was performed within 6 days from the trauma. Good cosmetic and functional results were obtained in 97 patients (91%). Early or late severe intracranial infections were noted in 3 cases (3%). No case of neurological deterioration because of an early operation and no case of delayed CSF leak was found.
Looking at our experience and the data reported by other Authors the decision making in the management of patients with frontobasal injury is based on the following steps:

1) general assessment of the patient's conditions;

2) assessment of the craniofacial fractures and their effects;

3) selection of candidates for surgical treatment;

4) choice of timing and the type of surgical procedure.

A successful outcome is better achieved when:

- a multidisciplinary team approach during all the steps of the decision-making is pursued;

- an immediate diagnosis and treatment of the acute life-threatening lesions is obtained;

- an early, one-stage, and complete repair of the craniofacial bones is performed.

Key words: Frontobasal injuries, craniofacial fractures, management.

Introduction

Frontobasal injury is due to a trauma of the central or lateral mid- or upperface.

The blow hits firstly the craniofacial bones and an isolated frontobasal fracture can occur. Because of the particular anatomy of the region, the fracture involves one or more of the frontal, temporal, sphenoidal, ethmoidal, nasal, and zygomatic bones. Often complex, comminuted and displaced bone fragments are produced. The precise understanding of the three-dimensional configuration of the fractured segments and their early and definitive repair are the basis for a successful treatment (8,17).
High energy traumatisms can involve the anterior cranial base and the adjacent structures, directly or by mean of displaced bone fragments, with a potential damage of the dura, the cranial nerves, the brain, and the eye. A frontobasal fracture associated with brain injury, CSF leak, damage to the olfactory, optic and oculomotor nerves, and eye injury can occur. Finally lesions also to the cervical spine, the trunk, and the extremities can be eventually associated (10,13-15,17).Therefore successful treatment of patients with frontobasal injury starts from the surgeon's appreciation of the associated nonfacial injuries (17).
The initial assessment of the patient and the timing and techniques of the craniofacial bones repair are the main issues still discussed (1,2,5,7,8,11,12,14,15,17).
By analyzing a series of 142 patients with a frontobasal fracture the Authors will emphasize the decision-making process guiding their management.

Material and Methods

We retrospectively analyzed 142 patients suffering a frontobasal injury severe enough to produce a frontobasal fracture. They were managed by our Neurosurgical and Maxillofacial Surgery Divisions between 1987 and 1997, accounting for the 5.5% of 2,557 facial traumas and the 11% of 1,271 cranial traumas managed in the same period.
125 patients (88%) were males, and 17 (12%) females. The age was between 13 and 76 years, with a mean of 31.2 years.

All patients underwent extensive clinical examination in the emergency department and early CT scan with careful visualization of craniofacial bones and intracranial structures, by appropriate radiological techniques. Cervical spine and thorax X-rays were carried out in all patients. Other body segments were explored as needed.
Frontobasal fractures were classified in central, lateral, and combined, as proposed by Sturla (23).
As far as an open cranial lesion was diagnosed a prophylaxis with wide range antibiotics was started. Life-threatening lesions were treated by the appropriate specialist. Craniofacial bone repair was usually performed as early as allowed by the general and neurological conditions of the patient.
Out of 142 patients managed, 107 (75%) underwent surgical treatment. In 62 patients (58%) with fractures involving the anterior wall of the frontal sinus, the orbital roof and the nasal or zygomatic bones without intracranial surgical lesions, the operation was performed by the maxillofacial surgeon only. The other 45 patients (42%), harboring intracranial surgical lesions and/or fractures of posterior wall of the frontal sinus, were operated on by a combined team (neurosurgeon and maxillofacial surgeon).
The surgical procedure was performed following some general rules:

- wide exposition of the fractures (usually by a coronal flap);
- intradural operation and dural repair by Lyodura, when needed;
- basal repair, by debridement of bone fragments, cranialization of the frontal sinus, reconstruction by bony fragments or grafts (from split cranium or iliac crest), and covering by pericranium flap;
- craniofacial repair, by elevation of bone fragments, reconstruction of bone defects by bone fragments or grafts, and fixation by miniplates and/or wires.

Standard antibiotics (second or third generation cephalosporin) were administered intravenously for a week and orally for another week. In grossly contaminated wounds intravenous antibiotics were given for two weeks and chosen as far as possible from the antibiogram.
Serial post-operative CT scans were performed to assess bony reconstruction, follow-up the intracranial injuries, and detect eventual late complications.
Follow-up ranged from 1 to 10 years, with a mean of 3.2 years.

Results

Mechanism of injury

The causes of injury are listed in Table 1. Motor vehicles accidents accounted for 57% of cases, work accidents for 14%, falls for 10%, sport accidents for 9%, and assaults for 6%. Therefore in most cases injury followed a high velocity trauma.

Frontobasal fractures

Central frontobasal fractures were found in 82 cases (58%), lateral in 28 (19%), and combined in 32 (23%). In 68 cases (48%) the bony fragments were significantly displaced. The frontal sinus was injured in 124 cases (87%): the anterior wall only was fractured in 74 patients (52%), both anterior and posterior walls in 50 patients (35%).
The frontobasal fracture was the only noticeable lesion in 27 cases (19%).

TABLE 1. Mechanism of injury

Cause	N.of patients (%)
Motor vehicle accident	81 (57%)
Work accident	20 (14%)
Fall	14 (10%)
Sport accident	13 (9%)
Assault	8 (6%)
Other	6 (4%)
Total	142 (100%)

Associated lesions

In 115 patients (81%) one or more of the lesions listed in Table 2 were associated with the frontobasal fracture. Maxillofacial fractures were the most common finding (79 cases = 56%), followed by lacerated wound of the facial skin (60 cases = 42%).
Intracranial lesions were found in 47 cases (33%), harbouring one or more of the following: evident CSF leak and/or pneumocephalus in 19 cases (13%), extra- or subdural haematoma in 16 (11%), brain contusion or intracerebral haematoma in 15 (11%), diffuse brain injuries in 4 (3%).
Intraorbital lesions were found in 14 cases (10%): optic nerve lesions in 3 cases (2%), ocular globe rupture in 2 (1%), ocular muscles and/or oculomotor nerves lesions in 9 (6%).
A polytrauma was found in 10 cases (7%), with unstable cervical lesions in 2 (1%), life-threat-

TABLE 2. Lesions associated with a frontobasal fracture in 142 patients

Lesions	N.of patients (%)
Maxillo-facial fractures	79 (56%)
Lacerated wound of facial skin	60 (42%)
Intracranial lesions:	47 (33%)
- evident CSF leak/pneumocephalus	*19 (13%)*
- extra- or subdural haematoma	*16 (11%)*
- brain contusion	*15 (11%)*
- diffuse brain injuries	*4 (3%)*
Intraorbital lesions:	14 (10%)
- ocular muscles/oculomotor nerves lesions	*9 (6%)*
- optic nerve lesions	*3 (2%)*
- eye globe injury	*2 (1%)*
Polytrauma:	10 (7%)
- limbs fractures	*6 (4%)*
- thoracic and/or abdominal lesions	*5 (3%)*
- unstable cervical lesions	*2 (1%)*
None	27 (19%)

ening thoracic and/or abdominal lesions in 5 (3%) and limbs fractures in 6 (4%).

Treatment

Conservative treatment was chosen in 35 patients (25%), harbouring a linear or minimally displaced fracture, without persistent CSF leak. The other 107 cases (75%), with displaced and/or comminuted fractures, or with linear fracture and persistent CSF leak, underwent surgical treatment.

Timing of operation

Emergency treatment, within 24 hours from the trauma, was performed in 20 cases (19%), harbouring a craniocerebral wound or an expanding intracranial mass (Table 3).
In 50 cases (47%) the operation was performed as early as possible, from 1 to 6 days after the trauma. 37 cases (34%) underwent surgical treatment later, between 7 and 15 days, either because of their unstable neurological and/or general conditions or because they were referred lately from peripheral hospitals.

TABLE 3. Timing of one-stage surgical repair of fronto-basal and eventually associated maxillo-facial fractures

Timing	N.of patients (%)
Less than 24 hours	20 (19%)
1-6 days	50 (47%)
7-l5 days	37 (34%)
Total	107 (100%)

TABLE 4. Cranial procedures performed in 107 patients

Procedure	N.of patients (%)
Intradural procedure	12 (11%)
Cranialization of frontal sinus	38 (36%)
Base repair by pericranium flap	28 (26%)
Base repair by bone grafts	12 (11%)
Fixation by miniplates	86 (84%)

Surgical procedure

Coronal approach was used in 82 cases (76%), translesional in 18 (17%), and supraciliar in 7 (7%).
An intradural procedure was performed in 12 cases (11%), for removing an expanding intradural mass and/or repairing basal dural lacerations (Table 4).
Cranialization of frontal sinus was done in 38 cases (36%), followed by pericramium flap in 28 (26%). In the first 10 cases sinus cranialization was performed without final covering of cranial base by pericranium flap.
In 12 cases (11%) there was a large bone defect. It was repaired by bone grafts, obtained from the iliac crest (2 cases) or from the calvarium (10 cases).
In 86 cases (84%) bone fragments and/or bone grafts were fixed by miniplates only or by miniplates and wires, in the first 26 cases (16%) by wires only.

Complications

Good cosmetic and functional results were obtained in 97 patients (91%). In 10 patients (9%) either maxillary malocclusion (1 case), orbital dystopia (2 cases), enophtalmus (1 case), depressed naso-frontal junction (2 cases), or skin irregularities due to incomplete osteogenesis (4 cases) appeared. All of these

TABLE 5. Complications in 107 surgically treated patients

Complications	N.of patients (%)
Intraoperative death	1 (1%)
Early meningitis	2 (2%)
Delayed meningitis	1 (1%)
Bone flap osteomyelitis	1 (1%)
Post-traumatic deformities:	10 (9%)
- maxillary malocclusion	*1 (1%)*
- orbital dystopia	*2 (2%)*
- enophtalmus	*1 (1%)*
- depressed naso-frontal junction	*2 (2%)*
- incomplete ostheogenesis	*4 (4%)*

has been submitted to a second delayed operation with good results.
No delayed CSF leak was noted (Table 5).
Uncontrollable intracranial infections occurred in 3 patients (3%). In 2 cases early meningitis was complicated by encephalitis and subsequent death. In 1 case a delayed recurrent meningitis appeared; notwithstanding reoperation and intensive antibiotic treatment it was finally complicated by encephalitis and the patient died 3 years after the initial trauma. All these cases underwent cranialization of frontal sinus without pericranium flap. Since this procedure was routinely done, no intracranial infection was noted.
Bone flap ostheomyelitis appeared in 1 case (1%) and was successfully treated by removal of the flap, systemic antibiotics and delayed bone reconstruction.
One intraoperative death (1%) occurred in a severe polytrauma, that underwent an emergency operation because of an expanding intracranial mass.

Decision Making

Frontobasal injury has the peculiar feature of involving simultaneously mid- and upperface bones, anterior skull base, intracranial structures, and intraorbital content.
High velocity traumatisms, like motor vehicle accidents and fall, are the most common mechanism of injury. In our series they were found in 67% of patients, and similar rates are reported in other series (3,10,13-15). Therefore many patients suffer from severe frontobasal injuries, and some can be affected by multisystem injuries due to a polytrauma.
The decision-making process starts with an accurate initial assessment of the patients conditions, looking firstly at the associated intracranial and systemic lesions. Actually some of them are life-threatening and need immediate treatment. In a second time the craniofacial lesions are examined. Their assessment will give the information for the next step of the decision making process: the choice of the most appropriate treatment.

General Assessment

The initial assessment follows the usual rules applied to every trauma patient: airway, breathing, and circulation are the first concern, then nervous system, thorax, abdomen, spine and limbs are examined. General inspection and blood samples, followed by head CT scan, routine X-rays of the cervical spine and of the thorax are the basic steps. Other appropriate instrumental examinations are applied as needed.
A multidisciplinary team approach is fundamental: anaesthesiologist, trauma surgeon, neurosurgeon, and maxillofacial surgeon are the most frequently involved; selected cases require ENT surgeon, ophthalmologist, plastic surgeon, and orthopaedic surgeon skills.
These concerns are widely justified by the high percentage of patients harbouring lesions in adjacent and distant high functional structures after severe frontobasal injuries. In our patients suffering from a frontobasal injury severe enough to produce a craniofacial bones fracture, associated lesions were found in 81% of cases. The most frequent lesions were other facial bones fracture (56%) and lacerated wound of the facial skin (42%). Intracranial lesions were found in 33% of cases, intraorbital lesions in 10%, and multisystemic lesions due to a polytrauma in 7%. Similar experience is reported by other Authors (2,12,15,17,20).
Some of intracranial and systemic lesions are life-threatening. Therefore the first concern of the decision making process in severe frontobasal injuries is to diagnose and treat immediately the acute life-threatening lesions.

Assessment of frontobasal fractures

The assessment of frontobasal fractures is based on clinical and radiological examination. Clinical findings include direct and indirect signs. Direct signs are deformation and/or instability of the related facial region. Indirect signs are local

edema and ecchymosis, cerebrospinal fluid leakage from the nose or the ear, periorbital or subconjunctival ecchymosis, orbital emphysema, scalp, orbital or supraorbital lacerations, anaesthesia of the supraorbital nerve, ptosis, ocular movements disorders, blindness, globe injuries (7,8,10,17). Both direct and indirect signs should be carefully researched, mainly in less severely injured patients, and the indication to the CT scan examination should be given at the minimum doubt.

High resolution CT scan in horizontal and, when possible, in coronal planes usually allows to detect and classify the fracture. Olson reports that in his series a frontal sinus fracture has been diagnosed by initial CT scan in 94% of cases (19). CT scan shows also indirect signs of a frontobasal fracture, such as intracranial air and air-fluid level within paranasal sinuses. Tridimensional reconstruction of the cranio-facial frame is useful to facilitate the diagnosis and the treatment planning.

The classification of frontobasal fractures is based on their anatomical location and the pattern of bone segmentation and bone displacement (16). Basically frontobasal fractures are defined as central, lateral, or combined. Another crucial factor that must be noted is the involvement of paranasal sinuses and anterior skull base. Finally the type is referred: linear or comminuted, with or without bone fragments displacement (3,22,23). These indications are fundamental for a better understanding of the fracture effects and for correct planning of their treatment.

Surgical treatment

The surgical treatment of frontobasal injuries often involves different specialities. The Neurosurgeon is responsible for the intracranial and the anterior skull base lesions. The Maxillofacial Surgeon treats the anterior wall of the frontal sinus, the orbital roof, and the nasal and zygomatic lesions, other than the associated mid- and lower face fractures. The ENT Surgeon is addressed to the nasal (and paranasal) region lesions, thus often overlapping the maxillofacial surgeon's activity. The Ophthalmologist is involved in the ocular globe lesions and the Plastic Surgeon in the reconstruction of wide skin losses of the face. These are general rules that can be modified following the specific skills and experience in any local reality. In many cases either maxillofacial surgeon, ENT surgeon or plastic surgeon alone take care of the patient with frontobasal fractures without intracranial lesions (2,3,5,8,11).

In our experience frontobasal fracture were treated by a combined maxillofacial and neurosurgical team in 42% of cases, when the fracture involved the anterior skull base or intracranial lesions were associated. In the other 58% of cases the maxillofacial surgeon alone provided the surgical repair of the patient's lesions.

Indications. In the frontobasal injured patient surgery is basically required either to repair skin wounds, craniofacial fractures, and dural lacerations, or to remove intracranial masses or bone fragments impinging on the optic nerve. The surgical treatment of a frontobasal fracture is indicated when the fracture is displaced or when a linear fracture is associated with a persistent CSF leakage. The Authors did not operate on patients with linear fracture associated with a small amount of intracranial air and/or CSF leakage that stopped within 10 days from the trauma. These indications are shared by many (12-14,17,20). Some recommends a more aggressive treatment in the latter cases (15,21). No statistically significant difference in the rate of occurrence of meningitis has been shown between conservatively and surgically treated patients with transient CSF leakage (4). Prophylactic antibiotics were given in all the patients with direct or indirect signs of an open fracture, either if surgically or conservatively treated. Antibiotics use is widely advocated (10), but a statistical evidence of their benefit in preventing intracranial infections is still lacking (4).

Intracranial masses are removed following the general rules of neurotraumatology. Extradural and subdural haematomas more than 5 mm. thick and intracerebral haematomas more than 3 cm. in diameter are evacuated (20).

Surgical decompression of the optic nerve is considered when the patient refers an abrupt or progressive visual deterioration and CT scan shows a compromise of the optic canal by fracture fragments (13). In unconscious patients only the radiological criteria are available and severe primary lesions of the optic nerve can be overlooked. This explains why only 20-50% of the patients shows substantial visual improvement after the decompression (13,23).

Timing. Acute life-threatening lesions require an emergency operation.

As to frontobasal fractures an early treatment of all the lesions within 5-6 days from the trauma is widely advocated (1, 3, 4, 10, 11, 14, 15, 17, 20). Many advantages are reported. Early surgical repair:

- prevents infection by avoiding accumulation of secretions in the paranasal sinuses and by reducing the time of contact between contaminated regions and intracranial contents;
- gives better cosmetic and functional results, by avoiding scar tissue formation and resorption of bony edges;
- reduces hospital stay;
- facilitates the nursing in severely ill patients.

Some Authors advise the operation within 6-48 hours from the trauma (8,11,21).

The only contraindications arise in patients with unstable general conditions and/or severely impaired neurological conditions with raised intracranial pressure. If these rules are followed, early repair of craniofacial bones fractures does not appear to reduce survival (5).

In our series 66% of patients were operated on within 6 days. We found 1 intraoperative death in a severe polytrauma patient that underwent an emergency operation to evacuate an expanding intracranial mass. Otherwise we did not observe a further impairment of general or neurological conditions due to the operation. Delayed craniofacial surgery, between 7 and 15 days, usually took place because of a late referral from peripheral hospitals.

Procedure. A sequential and combined approach is the key in the presence of craniofacial trauma. Considering the anatomy as well as the pattern of craniofacial fractures, it is obvious that any manipulation of the skull base involves the midface fractures and viceversa (21). Craniofacial injuries should be regarded as a single entity and the repair is often a combined procedure involving the neurosurgeon and the maxillofacial surgeon. First the dura is repaired, isolating the cranial contents, then fractures of the cranium and the face are treated following the principles of craniofacial surgery utilized in the correction of craniofacial deformities (8).

A correct procedure starts from an adequate exposition of the fractures. This is usually given by a coronal cutaneous flap; subciliary and intra-oral incisions are used to expose facial fractures when needed. Coronal flap avoids anaesthetic scars in the middle and upper face. At the same time this approach allows to preserve a wide vascularized pericranium flap, that will be useful to cover the injured anterior skull base. A direct inspection of the actual fractures pattern is then completed by periosteum elevation. The loss of periosteum has been advocated as a cause of late ostheonecrosis (18). Many Authors deny the appearance of this complication (7,8,10,11,14,15,17). We observed it in 4 cases out of the 28, where a pericranium flap was used, late irregularities of the skin overlapping the fracture rims and the craniotomy holes. They were possibly due to an imperfect ostheogenesis related to the loss of periosteum covering.

Frontal mono- or bilateral craniotomy is then performed and completed if needed by the removal of the frontal bar. This allows a wide

approach to the anterior skull base with a minimal retraction of the frontal lobes (21).
Only in selected cases can the fracture be sufficiently repaired via tranlesional or supraciliar approach. In our series we used the coronal approach in 76% of cases, translesional in 17%, and supraciliar in 7%.
The next step is the intradural procedure and the dural repair, if they are needed. Dural repair is performed either intradurally or extradurally. Intradural approach is done when:

- the dura must be open to evacuate a subdural haematoma and/or a brain contusion or haematoma;
- the anterior skull fracture is composed and does not need a surgical repair.

In the other cases extradural repair is preferred to avoid further contaminations of the brain.
The anterior skull base fractures are then addressed and the bony fragments debridden. Therefore the bony defects are repaired by autologous bone grafts, obtained either from the same fragments or from split calvarium. Other autologous bone, from iliac crest or ribs, is usually not required.
In cases of extensive injury of the posterior wall of the frontal sinus, cranialization is the method of choice (6,8,11,13,15,21,24). A complete removal of the sinus mucosa is stressed. Finally naso-frontal duct and dead spaces of the sinus are filled by bone dust, hydroxyl-apatite and tissucol. Expressely shaped plugs of bone can be inserted in the naso-frontal duct.
The frontal barr is reconstructed and fixed by miniplates.
The anterior skull base is finally covered by a wide pericranium flap, building a vascularized curtain that separates intracranial contents from nasal cavities. Actually we did not observe any lethal intracranial infection since we routinely use this method.
The last steps will be the reconstruction of the cranio-facial bones. The facial complex is reconstructed following a centripetal sequence of repair, as described by Gruss (8). Correct facial projections and width, together with normal occlusion are re-established.

CONCLUSIONS

The decision making in frontobasal injured patients relies on:

- a multidisciplinary team approach during all the steps of the management;
- an immediate diagnosis and treatment of the acute life-threatening lesions;
- an early, one-stage and complete repair of the craniofacial bones.

Rigid fixation with miniplates and autologous bone grafting, mainly in glabellar and orbital region, is recommended. Failure to properly correct facial deformities at the time of early repair can lead to post-traumatic defects with soft tissue scarring, that may be of the utmost difficulty to correct by secondary operations.

References

1) Benzil DL (1992) Early single-stage repair of complex craniofacial trauma. Neurosurgery 30: 166-170.
2) Brandt KE, Burrus GL, Hickerson WL et al (1991) The Management of Mid-face Fractures with Intracranial Injury. The Journal of Trauma 31 (1): 15-19.
3) Burnstein F, Cohen S, Hudgins R et al (1997) Frontal Basilar Trauma: Classification and Treatment. Plast Reconstr Surg 99 (5): 1314-1321.
4) Clemenza JW, Kaltman SI, Diamond DL (1995): Craniofacial Trauma and Cerebrospinal Fluid Leakage: A Retrospective Clinical Study. J Oral Maxillofac Surg 53: 1004-1007.
5) Derdyn C, Persing JA, Broaddus WC et al (1989) Craniofacial Trauma: An assessment

of Risk Related to Timing of Surgery. Plast Reconstr Surg 86 (2): 238-245.

6) Donald PJ (1982) Frontal sinus ablation by cranialization. Arch Otolaryngol 108: 142-146.

7) Ellis E (1993) Sequencing Treatment for Naso-orbito-ethomoid fractures. J Oral Maxillofac Surg 51: 543-558.

8) Gruss JS, Pollock RA, Phillips JH (1989) Combined Injuries of the cranium and face. British Journal of Plastic Surgery 42: 385-398.

9) Haug RH, Adams JM, Conforti PJ et al (1994) Craniofacial Fractures Associated with Facial Fractures: A Review of Mechanism, Type, and Severity of Injury. J Oral Maxillofac Surg 52:729-733.

10) Helmy ES, Koh ML, Bays RA (1990) Management of frontal sinus fractures. Review of the literature and clinical update. Oral Surg Oral Med Oral Pathol 69: 137-148.

11) Ioannides C, Freihofer HP, Friens J (1993) Fractures of the frontal sinus: a rationale of treatment. British Journal of Plastic Surgery 46: 208-214.

12) Kral T, Zeutner J, Vieweg U et al (1997) Diagnosis and Treatment of Frontobasal Skull Fractures. Neurosurgical Review 20 (1): 19-23.

13) Kruse JJ, Awasthi D (1998) Skull-Base Trauma: Neurosurgical Perspective. The Journal of Cranio-Maxillofacial Trauma 4(2): 8-14.

14) Lee TT, Ratzker PA, Galarza M, et al (1998) Early Combined Management of Frontal Sinus and Orbital Facial Fractures. The Journal of Trauma: Injury, Infection, and Critical Care 44(4): 665-669.

15) Luce EA (1987) Frontal Sinus Fractures: Guidelines to Management. Plast Reconstr Surg 80 (4): 500-508.

16) Manson PN, Markowitz B, Mirvis S, et al (1990) Toward CT-based facial fracture treatment. Plast Reconstruct Surg 85: 202-212.

17) Marciani RD, Gonty AA (1993) Principles of Management of Complex Craniofacial Trauma. J Oral Maxillofac Surg 51: 535-542.

18) Merville LC (1974) Multiple dislocations of the facial skeleton. J Maxillofacial Surg 2:187-192.

19) Olson EM, Wright DL, Hoffman HT et al (1992) Frontal Sinus Fractures: Evaluation of CT Scans in 132 Patients. AJNR 13: 897-902.

20) Piotrowski WP (1992) The Primary Treatment of Frontobasal and Midfacial Fractures in Patients with Head Injuries. J Oral Maxillofac Surg 50: 1264-1268.

21) Raveh J, Vuillemin T (1988) The Surgical One-Stage Management of Combined Cranio-Maxillo-Facial and Frontobasal Fractures. Advantages of the Subcranial Approach in 374 Cases. J Cranio-Max-Fac Surg 16: 160-172.

22) Sakas DE, Beale DJ, Ameen AA et al (1998) Compound anterior cranial base fractures: classification using computerized tomography scanning as a basis for selection of patients for dural repair. J Neurosurg 88: 471-477.

23) Sturla F, Abnsi D, Buquet J (1990) Anatomical and mechanical considerations of craniofacial fractures: an experimental study. Plast Reconstr Surg 66: 815-820.

24) Wolfe SA, Johnson P (1988) Frontal sinus injuries: primary care and management of late complications. Plast Reconstr Surg 82:187-192.

Address for correspondence:
Dr. Sergio Zeme
Dipartimento di Neuroscienze. Divisione di Neurochirurgia
Via Cherasco 15. 10126 Torino. Italy