

SKULL BASE

Endoscopic endonasal approach to the craniocervical junction: the importance of anterior C1 arch preservation or its reconstruction

Approccio endoscopico endonasale alla giunzione craniocervicale: l'importanza di preservare o ricostruire l'arco anteriore dell'atlante

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SUMMARY

We report our experience with the endoscopic endonasal approaches (EEA) for different craniocervical junction (CCJ) disorders to analyse outcomes and demonstrate the importance and feasibility of anterior C1 arch preservation or its reconstruction. Between January 2009 and December 2013, 10 patients underwent an endoscopic endonasal approach for different CCJ pathologies at our Institution. In 8 patients we were able to preserve the anterior C1 arch, while in 2 post-traumatic cases we reconstructed it. The CCJ disorders included 4 cases of irreducible anterior bulbo-medullary compression secondary to rheumatoid arthritis or CCJ anomalies, 4 cases of inveterate fractures of C1 and/or C2 and 2 tumours. Pre- and postoperative neuroradiological evaluation was always obtained by magnetic resonance imaging (MRI), computed tomographic (CT) scanning and dynamic cranio-vertebral junction x-ray. Pre- and postoperative neurologic disability assessment was obtained by Ranawat classification for patients with rheumatoid arthritis and by Nurick classification for the others. At a mean follow-up of 31 months (range: 14-73 months), an improvement of at least one Ranawat or Nurick classification level was observed in 6 patients, while in another 4 patients neurological conditions were stable. Radiological follow-up revealed an adequate bulbo-medullary decompression in all patients and a regular bone fusion in cases of C1 and/or C2 fractures. In all patients spinal stability was preserved and none required subsequent posterior fixation. The endoscopic endonasal surgery provided adequate exposure and a low morbidity minimally invasive approach to the antero-medial located lesions of the CCJ, resulting in a safe, effective and well-tolerated procedure. This approach allowed preservation of the anterior C1 arch and the avoidance of a posterior fixation in all patients of this series, thus preserving the rotational movement at C0-C2 segment and reducing the risk of a subaxial instability development.

KEY WORDS: Endoscopic endonasal surgery • C2 odontoidectomy • Anterior C1 arch preservation • Spine instability

RIASSUNTO

Riportiamo la nostra esperienza con l'approccio endoscopico endonasale (EEA) in una serie consecutiva di 10 pazienti affetti da lesioni anteriori della giunzione cranio-cervicale. L'obiettivo dello studio è analizzare l'outcome di questi pazienti focalizzando l'attenzione sulla possibilità di preservare o ricostruire l'arco anteriore di C1, quale importante elemento di stabilità della giunzione cranio-cervicale. Dal gennaio 2009 al dicembre 2013, 10 pazienti con patologia della giunzione craniocervicale sono stati operati mediante approccio endoscopico endonasale. Le lesioni trattate includevano 4 casi di non riducibile compressione bulbo-midollare extradurale anteriore della giunzione (secondarie ad artrite reumatoide o anomalie della giunzione), 4 casi di fratture inveterate di C1 o del dente dell'epistrofeo e 2 casi lesioni tumorali. La valutazione clinica pre- e postoperatoria è stata effettuata mediante la scala di Ranawat per i casi di artrite reumatoide e di Nurick per gli altri. Il follow-up radiologico comprendeva invece RM, TC e RX con prove morfo-dinamiche per eventuale preesistente severa instabilità. Dopo l'approccio EEA puro alla giunzione craniocervicale, nessun paziente ha presentato un peggioramento neurologico, né si sono verificate significative complicanze. Al follow-up medio di 31 mesi (range 14-73 mesi), un miglioramento di almeno un livello della classificazione Ranawat o Nurick si è osservato in 6 pazienti mentre gli altri 4 sono rimasti stabili. Il follow-up neuroradiologico ha documentato in tutti i casi un'adeguata decompressione bulbo-midollare, mentre nei casi di frattura di C1 o C2 una regolare fusione ossea delle rime di frattura. Nessun paziente ha presentato segni di instabilità e non è stata pertanto necessaria alcuna procedura di stabilizzazione e fusione posteriore. L'approccio endoscopico endonasale garantisce un'adeguata esposizione delle lesioni antero-mediali della giunzione craniocervicale. Nella nostra serie di pazienti tale procedura ha permesso di preservare o ricostruire l'arco anteriore di C1, evitando quindi una sintesi posteriore e la relativa perdita di movimento rotazionale C0-C2 e l'instabilità subassiale.

PAROLE CHIAVI: Chirurgia endoscopica endonasale • Odontoidectomia • Risparmio arco anteriore dell'atlante • Instabilità spinale

Introduction

The craniocervical junction (CCJ) represents a surgical challenge because of the complexity of its anatomy and difficulty in accessing it in a minimally invasive manner. Anterior approaches for ventral pathology of the CCJ have traditionally involved open surgical procedures. The transoral-transpharyngeal approach is still the treatment of choice in a variety of diseases affecting the CCJ, including inflammatory (rheumatoid), post-traumatic atlantoaxial disease and neoplastic diseases^{1,2}.

This approach provides good exposure, but it includes some disadvantages such as a deep surgical corridor, a non-direct angle to the region, potential damages related to tongue retraction, palate splitting and upper airway swelling, risk of a postoperative oral flora contamination and prolonged intubation³.

Recently, Kassam et al.⁴ proposed a new approach: the endoscopic endonasal route (EEA). EEA provides a “natural” anterior corridor that avoids many of the transoral approach-related morbidities⁴⁻⁶. Furthermore, the endonasal endoscopic route allows a straightforward and better working angle with the possibility to preserve the anterior arch of C1 that is critical for the biomechanical stability of the occiput-C2 segment⁷⁻⁸.

We report our experience with the EEA for CCJ diseases to assess outcomes, advantages and limitations of this procedure, and to further stress the importance and feasibility of the anterior C1 arch preservation or its reconstruction, in most cases.

Materials and methods

Between January 2009 and December 2013, 27 patients underwent pure endoscopic endonasal approach for different CCJ diseases at our Institution. Among these, in 8 patients we were able to preserve the anterior C1, while in 2 patients the integrity of the anterior C1 arch was restored. The present series includes 3 males and 7 females. Mean age was 60.6 years (range: 18-81 yr). As reported in Table I, two patients had post-traumatic inveterate C2 Anderson-D'Alonso type II fractures with pseudo-arthrosis, 3 had irreducible anterior bulbo-medullary compression related to rheumatoid arthritis (basilar invagination and/or rheumatoid pannus), 1 presented with an atlanto-occipital malformation with platibasia and basilar invagination, 1 had a C1-C2 meningioma and 1 harboured CCJ cancer metastasis. Finally, the last two patients with atlas fracture non-union after conservative treatment (the second in combination with Anderson-D'Alonso type II odontoid fracture) were treated by a fully endoscopic endonasal anterior C1 arch reconstruction, in one patient combined along with the anterior transcervical screwing for the C2 fracture. Informed consent had been obtained at the time of surgery from all patients included in the study.

Preoperative evaluation always included physical neurological examination, magnetic resonance imaging (MRI), computed tomographic (CT) scanning with multiplane reconstruction and angiographic sequences, and dynamic craniocervical junction X-ray, when feasible without excessive risks, to evaluate a potential instability of the CCJ. Pre- and post-operative neurologic disability assessment was obtained by Ranawat classification for patients with rheumatoid arthritis and by Nurick classification for the other ones^{9,10}. Postoperative neuroradiologic workup was scheduled by immediate CT scan and by MRI at 1-3 and 6 months depending on the pathology (neoplastic or not), MRI yearly (to check for the myelopathy), CT scan (to verify the completeness of the arthrodesis process) and dynamic X-ray (to assess spinal stability). Serial office-based endoscopic controls were performed routinely after surgery. The first outpatient endoscopic control was carried out 3-4 days after surgery for removal of nasal tampons under endoscopic guidance. During this procedure, after removal of nasal tampons, nasal cavities and nasopharyngeal mucosa was inspected. Gentle suction and forceps were used to clean the nostrils and nasal cavities from any soft blood clot and/or nasal secretions up to the nasopharyngeal mucosa. In case of small mucosa dehiscence defect, fresh autologous blood was injected over the nasopharyngeal mucosa to speed up healing. Before discharge, usually after 1 week, and 15 days, 1 month and 3 months thereafter, all patients underwent endoscopic follow-up while awake to evaluate the status of nasal mucosa. The mean follow-up was 31 months (range: 14-73 months).

Surgical technique

All the EEA were performed by a multidisciplinary team composed of a senior neurosurgeon and the senior Ear, Nose and Throat (ENT) surgeon. Patients with anterior irreducible bulbo-medullary compression underwent endoscopic endonasal odontoidectomy with anterior C1 arch preservation (Fig. 1 a-f). The principal steps of this procedure have already been described¹¹⁻¹⁵. Briefly, surgical procedures were carried out using rod lens endoscopes (4 mm in diameter, 18 cm in length, 0° scope) with a high-definition camera. In all operations, we adopted the neuronavigation system and, in some cases of fractures, fluoroscopy was used to check the correct positioning of cannulated screws and plates. Routinely, the posterior part of the hard palate was thinned by drilling out the outer bone layer, making the hard palate more flexible to enhance the angle of “nasopalatine line” (Fig. 2a). Then, after the identification of anterior C1 tubercle by anatomical landmarks and neuronavigation, a small linear incision (about 3 cm) was made in the midline of the nasopharyngeal mucosa (Fig. 2b). After subperiosteal preparation, all efforts were made to preserve the anterior arch of the atlas by drilling the odontoid base which weakens in its api-

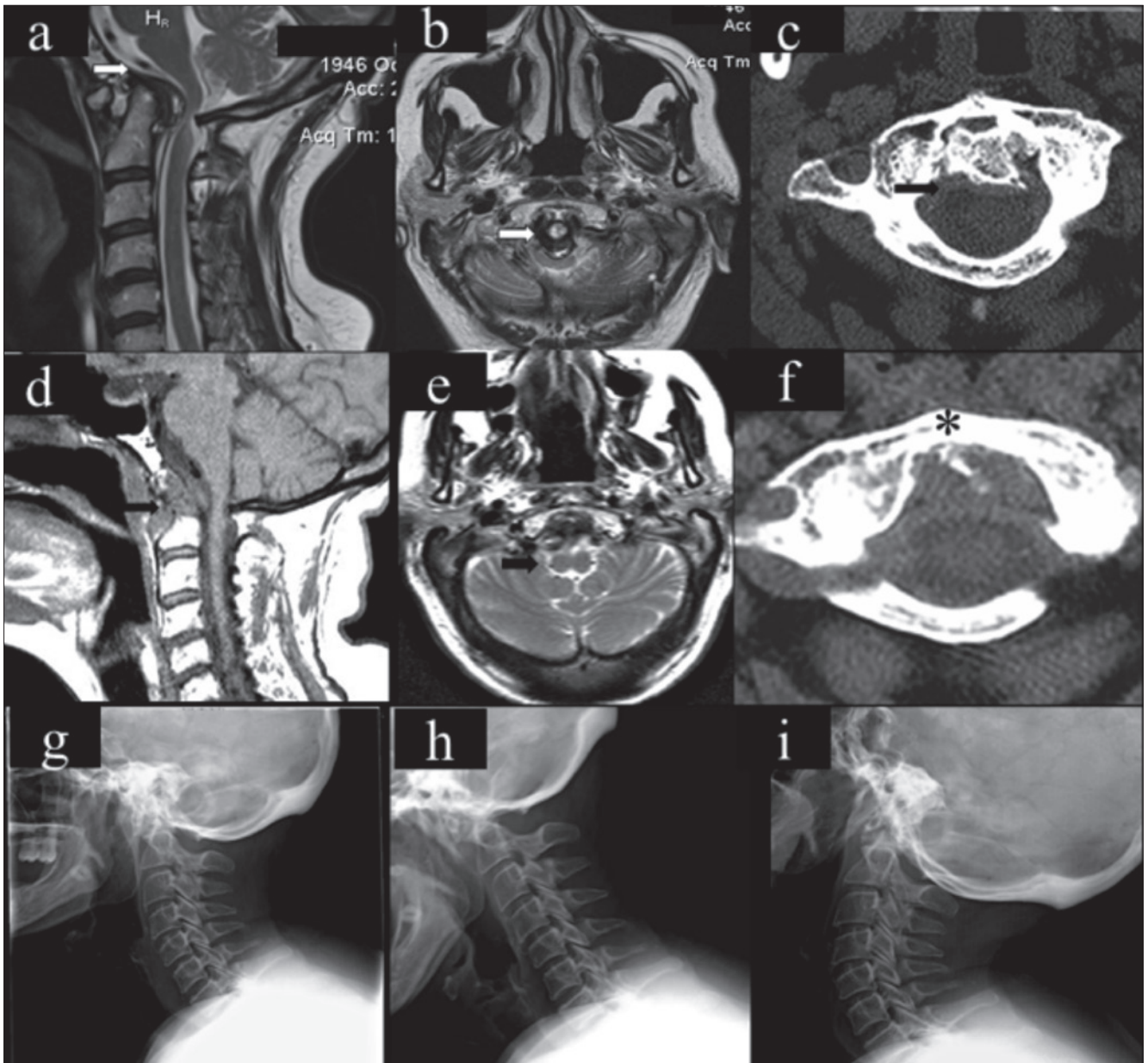


Fig. 1. Patient 2 (see Table I). A 65-year-old woman, with a long-lasting history of rheumatoid arthritis and recent onset of drop attacks. A, B. Pre-operative sagittal and axial T2 MRI images demonstrating basilar invagination and rheumatoid pannus with resulting severe bulbomedullary compression and associated myelopathy (white arrows). C. Pre-operative axial CT scan showing the peri-odontoid rheumatoid pannus (black arrow). D, E. Post-operative sagittal T1 and axial T2 MRI images showing the adequate spinal cord decompression after odontoidectomy and rheumatoid pannus removal, as highlighted by the increased cerebrospinal fluid space ventral to the bulbomedullary junction (black arrows). F. Postoperative axial CT scan illustrating the anterior C1 arch integrity (asterisk). G, H, I. One-year follow-up normal and dynamic cervical X-ray showing the absence of cranial settling and C1-C2 instability.

cal part so that it can be then easily pulled downward in the working area and removed along with any remaining compressive inflammatory lesions, using a combination of high-speed drill, ultrasonic bone curette and standard Kerrison rongeurs. The wide surgical cavity was subsequently inspected by angled lens endoscope and anatomical limits of resection were verified by neuronavigation (Fig. 2c-h). Finally, the nasopharyngeal defect was sutured (Fig. 2i). In the case of C1-C2 neoplastic lesions,

the surgery proceeded with the dural opening and tumour removal.

For inveterate C2 Anderson-D'Alonso type II fractures, the operation consists in an anterior transcervical odontoid screw fixation combined, at the same session, with a transnasal endoscopic approach to the odontoid. In these cases, the EEA allows inflammatory pannus removal (related to the pseudoarthrosis process) between the bony fragments and subsequent "in situ" anterior arthrodesis by

Table I. Summary of patient profiles.

RA = rheumatoid arthritis; **CCJ** = craniocervical junction; **EEO** = endoscopic endonasal odontoidectomy; **EEA** = endoscopic endonasal approach.

Patient no	Age (sex)	Primary Disease	Clinical status Preop/ Postop	Treatment
1	54 (F)	RA, irreducible bulbo-medullary compression secondary to basilar invagination and rheumatoid pannus	Ranawat Grade IIIa/II	EEO + RA pannus removal
2	65 (F)	RA, irreducible bulbo-medullary compression secondary to basilar invagination and rheumatoid pannus	Ranawat Grade III/II	EEO + RA pannus removal
3	49 (M)	Inveterate C1 fracture with cranial settling	Nurick Grade 0/0	EE C1 arch reconstruction (with autologous bone and titanium mash)
4	61 (F)	RA, irreducible bulbo-medullary compression secondary to basilar invagination and rheumatoid pannus	Ranawat Grade III/II	EEO + RA pannus removal
5	59 (F)	CCJ meningioma	Nurick Grade I/II	Complete removal with EEA
6	63 (F)	CCJ osteolytic cancer metastasis	Nurick Grade 0/0	Subtotal removal with EEA
7	77 (F)	Inveterate C2 fracture with pseudarthrosis (Anderson-D'Alonso type II)	Nurick Grade IV/IV	Anterior transcervical screwing + endoscopic anterior arthrodesis
8	18 (M)	Platibasia with basilar invagination and dens dislocation	Nurick Grade I/II	EEO
9	81 (F)	Inveterate C2 fracture with pseudarthrosis (Anderson-D'Alonso type II)	Nurick Grade III/II	anterior transcervical screwing + endoscopic anterior arthrodesis
10	79 (M)	Inveterate C1 and C2 fracture (Anderson-D'Alonso type II) with pseudo-arthritis	Nurick Grade IV/III	anterior transcervical screwing + endoscopic anterior arthrodesis + Endoscopic endonasal C1 arch reconstruction (plate and screws)

packaging the autologous bone and/or bone substitutes in the fracture space up to the underlying clivus. This combined approach may grant a minimally invasive direct access to the odontoid fractures for the removal of the pseudoarthrosis cloth aiming at cleaning the bone borders up to the normal cancellous bone just before the subsequent anterior screw fixation by self-tapping screws for a better fracture healing and spinal realignment.

In one patient, with a combination of anterior C1 arch fracture and odontoid fracture (Fig. 3ab), after anterior transcervical screwing and endoscopic endonasal arthrodesis of the odontoid fracture, we rebuilt the integrity of the anterior arch of C1 stumps by placing bone chips compressed between the bone under endoscopic control that were then fixed by three screws and one plate (Fig. 3cdef). This procedure was performed during EEA by insertion of

three guide wires under fluoroscopy and neuronavigation control into the edges of C1 fractures and into the tip of odontoid. The wires then guided the insertion of the cannulated screws inserted under imaging control until they reached the posterior cortex of the odontoid (Fig. 4a-h). The length of the screw was determined pre-operatively on the basis of CT scan and intraoperatively by neuronavigation supplemented by fluoroscopy. This step was useful just to guarantee temporary stabilisation of the autologous bone during the arthrodesis process and to avoid the further displacement of C1 articular masses. Finally, the last patient with a non-union anterior atlas fracture after conservative treatment that developed C1 lateral masses displacement with cranial settling, was treated by a fully endoscopic endonasal anterior C1 arch reconstruction using autologous bone graft and titanium mash.

C1 Arch Integrity	Posterior Fusion	External Orthosis	Follow-up (months)	Tracheostomy/extubation (days)	Re-start oral feeding (days)
Yes	No	rigid cervical collar / 1 month	73	No / 0	1
Yes	No	rigid cervical collar / 2 months	49	No / 0	1
Yes (following anterior C1 arch reconstruction)	No	rigid cervical collar / 1 month	37	No / 0	1
Yes	No	rigid cervical collar / 1 month	31	No / 0	1
Yes	No	no collar	27	No / 0	1
Yes	No	no collar	25	No / 0	1
Yes	No	rigid cervical collar / 2 months	21	No / 5	7
Yes	No	rigid cervical collar / 2 months	19	No / 0	1
Yes	No	rigid cervical collar / 2 months	17	No / 0	1
Yes (following anterior C1 arch reconstruction)	No	rigid cervical collar / 3 months	14	No / 2	3

Results

Adequate surgical exposure and working angle was achieved by the EEA in all 10 patients. In 8 patients we were able to preserve the anterior C1 arch, while in 2 post-traumatic cases it was reconstructed. The EEA allowed achievement of adequate decompression of the upper cervical medulla in all patients with basilar invagination and/or rheumatoid pannus and in the patient with a CCJ metastasis. The C1-C2 meningioma included in this series consisted in a relatively ventral small tumour (maximum diameter of 2.5 cm) determining symptomatic bulbo-medullary compression. The peculiar characteristics of this meningioma (antero-median location, small dimension, soft consistency, presence of the so-called “cortical cuff” between the meningioma and neurovascular structures and the limited dural tail) were particularly adequate

for the working angle granted by endoscopic endonasal approach and led to complete removal of the lesion with a limited osteo-dural dissection (see Fig. 5a-h). Thus, we were able to preserve the anterior C1 arch that represents in this case not only an element of stability, but also an important layer for reconstruction (see Fig. 5i). The reconstruction of relatively small dural defect was done with a multilayer technique including the harvesting of autologous bone dust anchored to the C1 arch along with the tip of odontoid and the suture of the mucosa as an additional reinforcing layer between cranial and nasal cavity to speed up healing and reduce the incidence of CSF leak. A lumbar drain was placed in the operating theatre and maintained for 5 days. Ambulatory endoscopic controls performed at 4, 7 and 15 days after surgery no showed signs of CSF leak.

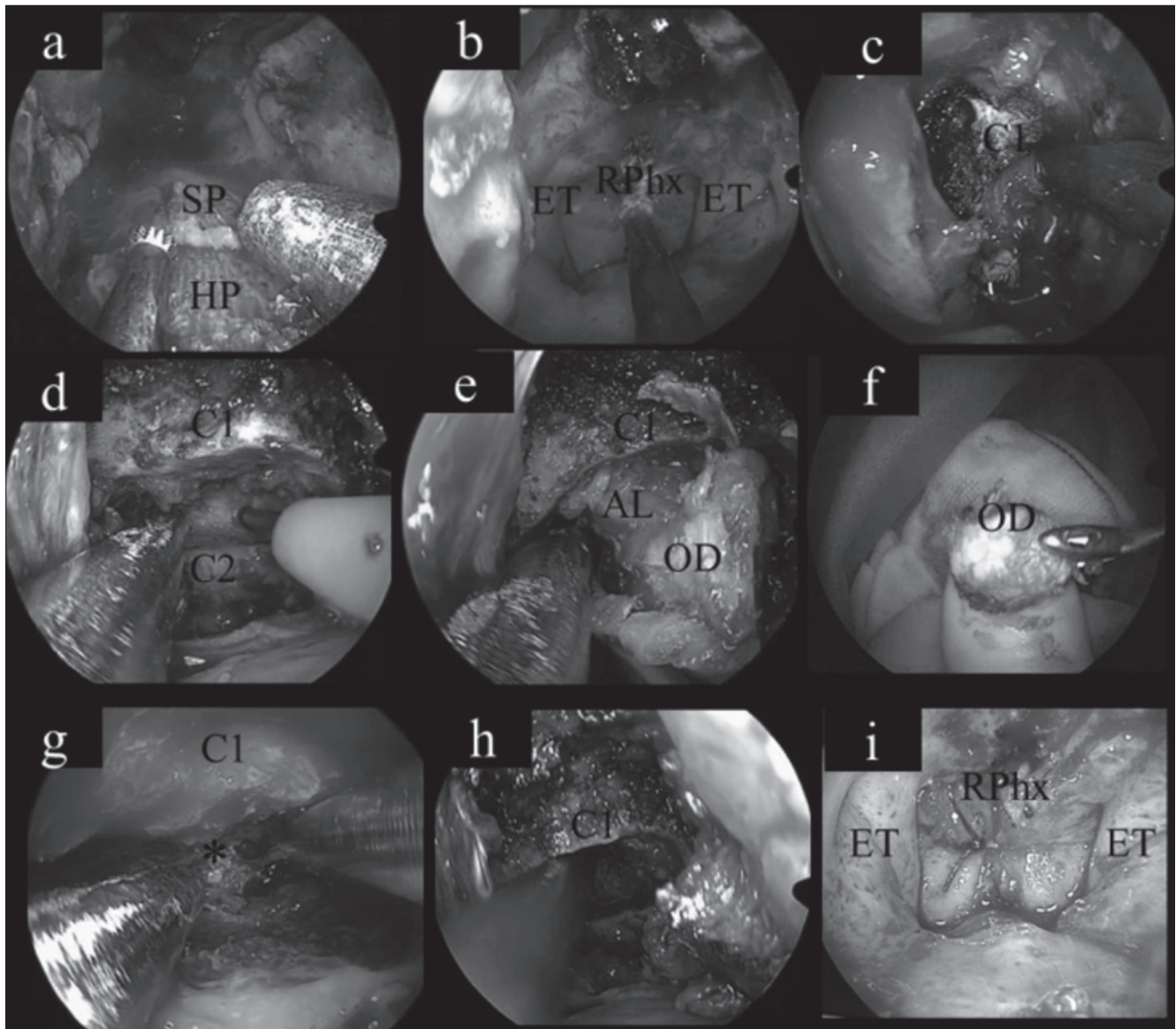


Fig. 2. Patient 2 (see Table I). Intraoperative endoscopic transnasal images. A. The posterior part of the hard palate was thinned by drilling out the outer bone layer with ultrasonic bone dissector, making the hard palate more flexible to enhance the angle of “nasopalatine line”. B, C. Linear incision in the midline of the nasopharyngeal mucosa and subperiosteal preparation of anterior C1 arch. D, E, F. Drilling out the base of odontoid process with preservation of the anterior C1 arch. This weakens the apex of dens that can be now easily pulled down by curette freed from ligaments and inflammatory tissue, and then removed with forceps. G. The rheumatoid pannus was removed by curette working behind the intact anterior C1 arch (asterisk). H. Pulsating surgical cavity after decompression with preservation of continuity of atlas ring. I. The suture of the mucosa in order to speed up the healing process. (SP: soft palate; HP: hard palate; ET: Eustachian tube, RPhx: rhinopharynx, OD: odontoid, AL: alar ligaments).

In two patients with inveterate C2 Anderson-D’Alonso type II fractures, treated by the anterior transcervical screwing combined with endoscopic trans-nasal anterior arthrodesis, radiological follow-up revealed regular bone fusion. Finally, in the two patients submitted to anterior C1 arch reconstruction, satisfying radiological bone ossification was reached in about 3 months. In all patients, spinal stability was preserved and none required a subsequent posterior fixation at a mean follow-up of 31 months (range: 14-73 months). No major complications occurred after surgery, no patients required intra- or postoperative repair of CSF leaks, intensive

care unit (ICU) staying, if needed, was short and uneventful, and oral feeding was rapidly re-started. Length of hospitalisation was usually less than 1 week. No patient worsened or developed new neurological deficits postoperatively. An improvement of at least one Ranawat or Nurick classification level was observed in 6 patients, while in the remaining four patients neurological conditions were stable (Table I).

Discussion

The most common disorders treated at the CCJ are degene-

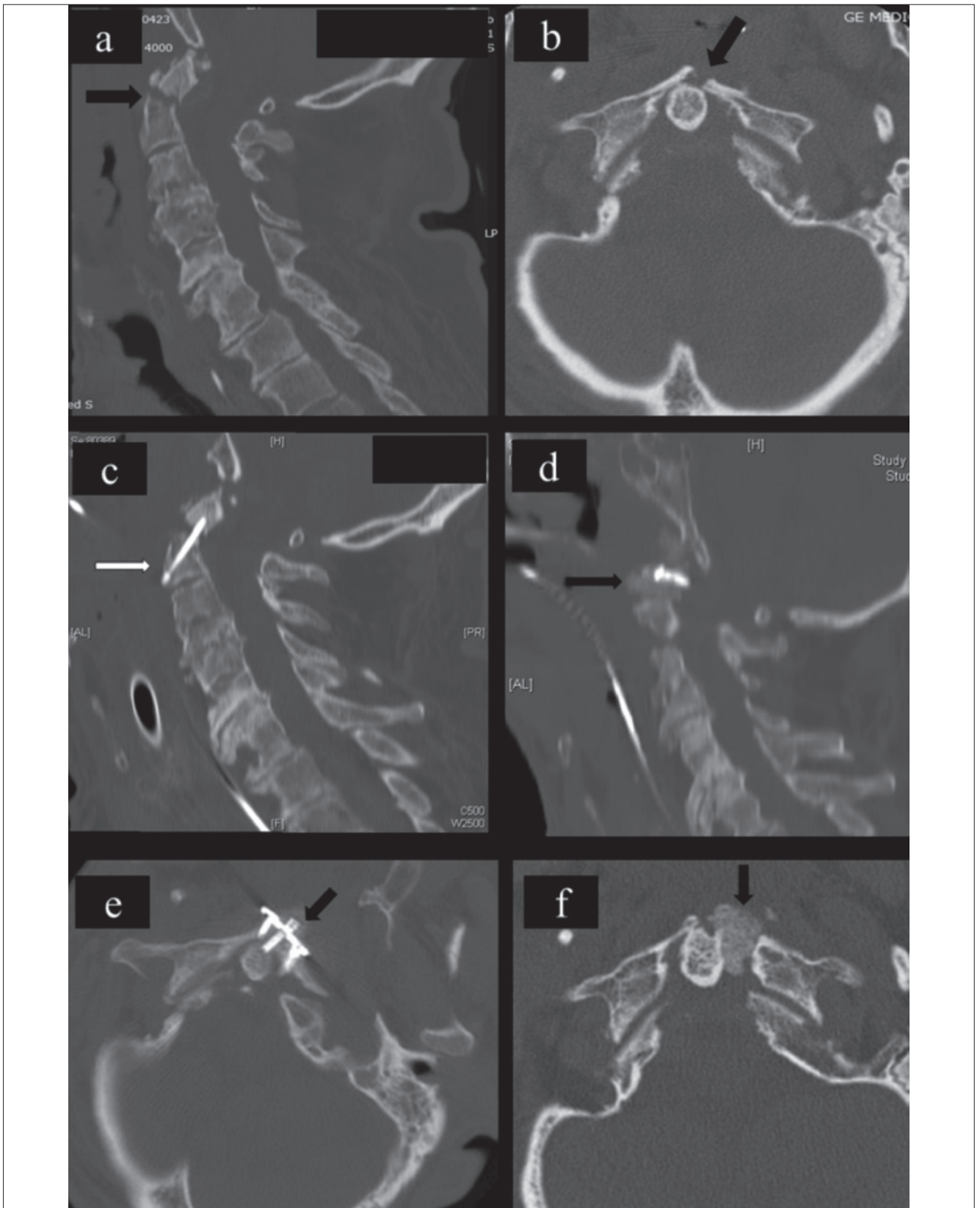


Fig. 3. Patient 10. A 79-year-old man with a previous cervical trauma (4 months ago) and inveterate anterior C1 arch and odontoid (Anderson-D'Alonso, type II) fractures with pseudoarthrosis. A. Preoperative sagittal CT scan revealing non-union type II odontoid fracture (black arrow). B. Preoperative axial CT scan revealing inveterate anterior C1 arch fracture (black arrow). C, D, E, F. Postoperative sagittal and axial CT scans showed anterior odontoid screw fixation (white arrow) combined with endoscopic transnasal C1 arch reconstruction by placing autologous cancellous bone chips to bridge the osseous gap and then fixed by plate and screws for future arthrodesis (black arrows).

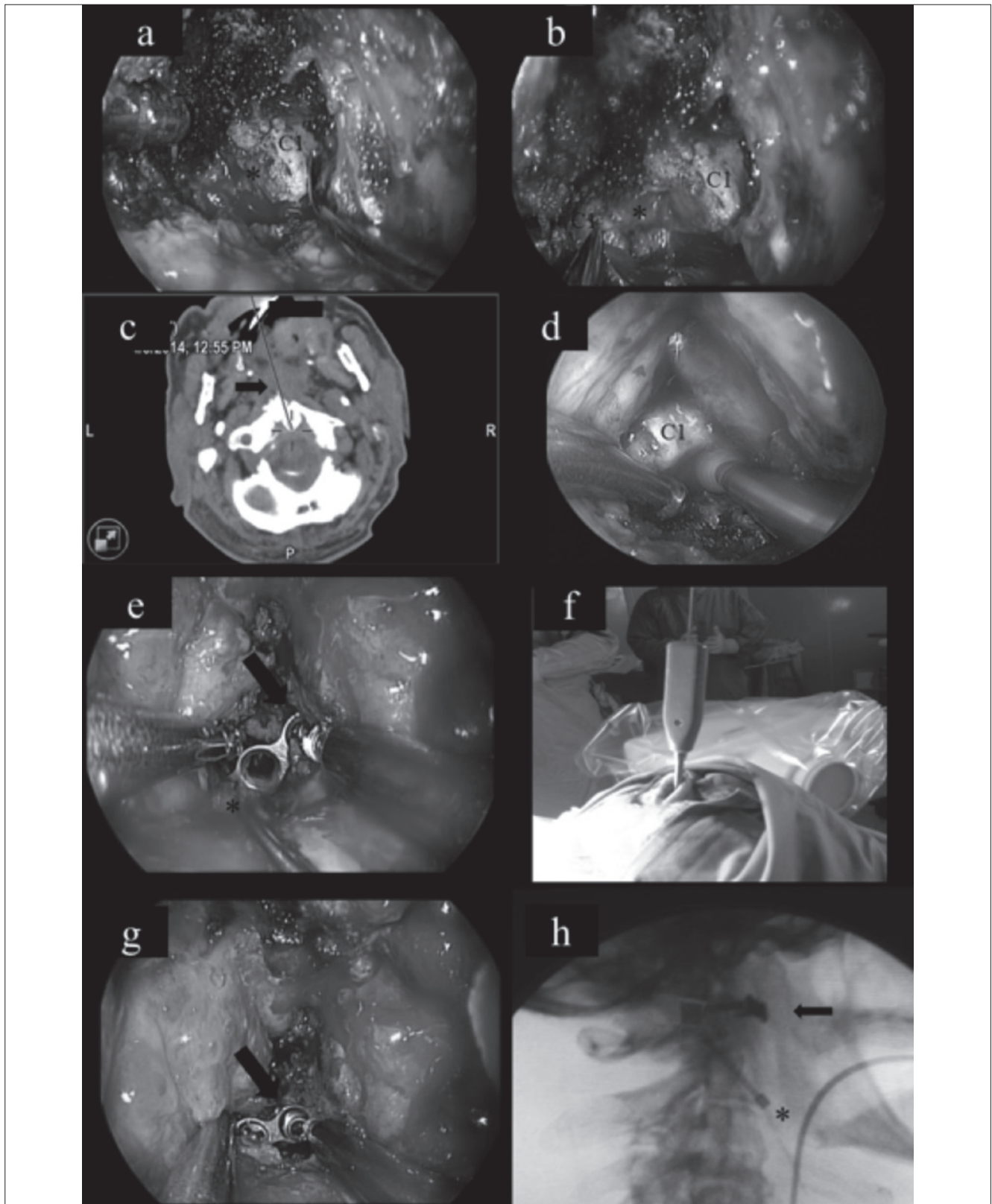


Fig. 4. Patient 10 (see Table I). A, B. Intraoperative endoscopic transnasal images showing sub-periosteal preparation of the anterior C1 arch and non-union fracture with pseudoarthrosis inflammatory pannus in between. C, D. Drilling of the edges of odontoid fracture below anterior C1 arch after verification with the neuronavigator. The EEA allows the inflammatory pannus (pseudoarthrosis) removal and cleaning the bone borders up to the normal cancellous bone just before the subsequent anterior C2 screw fixation and C1 arch plating. E, F, G. Reconstruction of the anterior arch of C1 by positioning bone chips compressed between the bone edges and a plate fixed the insertion of cannulated screws. H. Final intra-operative fluoroscopy image showed the correct placement of plate (black arrow) and cervical screw (asterisk).

erative or posttraumatic atlantoaxial disease, meningiomas, chordomas and other rare bony tumours. Rheumatoid arthritis is the most common inflammatory disease involving the spine with predilection for the upper cervical spine. Surgery is usually reserved to the patients with symptomatic CCJ instability, basilar invagination with odontoid dislocation, or irreducible upper spinal cord compression by rheumatoid pannus. Treatment of anterior bulbo-medullary junction compressions can be performed by different surgical procedures and is the type of the approach dictated by the nature and extension of the lesion^{3 11-16 17-33}.

Transoral and transcervical approaches, and recently a transnasal approach to the CCJ, are the most widely used. The procedures have different trajectories, working angles and extents of exposure; therefore, several considerations should be taken into account to tailor the most appropriate surgical strategy for the different patients³. The transoral-transpharyngeal technique is still considered the gold standard anterior approach and still represents the most experienced technique^{1 2}.

However, this surgical technique is not properly minimally-invasive in the general sense of the respect of the anatomical planes and/or its precise layer-by-layer reconstruction^{13 14}. In fact, this approach often involves the splitting of structures such as the soft palate, mandible and maxilla. However, Visocchi et al. proposed the use of a 30° endoscope for the transoral approach to avoid full soft-palate splitting, hard-palate splitting or extended maxillo/mandibulotomy. In fact, the use of the endoscope allows direct vision in all directions by rotating the instrument, and the authors concluded that with the aid of an endoscope, abnormalities as high as the mid-clivus can be visualised without extensive soft- or hard-palate manipulation³⁵⁻³⁹.

Furthermore, the transoral route is not a straightforward approach to the lesion and could present a deep surgical field with a small and asymmetric angle of working related to the mouth opening and upper direction. The transoral approach also includes the risk of bacterial contamination secondary to oral cavity penetration, prolonged postoperative intubation and nasogastric tube feeding, along with potential effects on phonation. Finally, healing of the oropharyngeal incision can be difficult because of wound contamination by saliva and bacterial flora.

All these issues have served as a stimulus to explore alternative and less invasive treatment options^{4-6 11-16}. Advances in endoscopic technology and equipment¹⁷⁻¹⁹ have allowed the use of minimally-invasive techniques in the CCJ.

In 2005, Kassam et al.⁴ first reported on EEA for resection of an odontoid process and rheumatoid pannus in a 73-year-old woman. At present, few other similar cases have been reported in literature^{4 11-14 20-33}.

The EEA is a more direct and straightforward approach with a shorter working distance in comparison with the transoral ones, offering good exposure and working area

from the clivus down to C2. All these concerns represent, in our opinion, a significant advancement in the management of irreducible compressive lesions of the anterior CCJ. The decompression is at least as effective as that obtained with the other approaches with a potential lower morbidity, and greater respect of the cervical spine biomechanics.

The lower morbidity can be attributed to earlier extubation, prompt oral feeding and lower risk of bacterial wound contamination because the mucosal defect created by a transnasal approach is linear, smaller and above the level of the soft palate^{4 11-14}.

Furthermore, by this approach, we were able to spare the hard and soft palate and to remove only a small portion of the posterior nasal septum preserving most of the nasal mucosa, thus leaving the physiological mechanisms of breathing and phonation unaffected. Finally, the use of an endoscope has some advantages in itself, including the close-up vision and a larger field of vision in the depth, which are benefits enhanced by the use of dedicated angled lenses. However, it should be noted that there are some limitations to this approach. The lesion must be located almost in the midline and above the "nasopalatine line"⁴ and, occasionally, partial posterior drilling of the hard palate is needed to gain a more caudal access¹¹⁻¹⁴. Regardless of the learning curve, similar to the transoral approach, some limitations still remain in terms of a narrow and deep surgical corridor; thus, these procedures should be performed only in selected centres by a multidisciplinary, well trained team in endoscopic techniques.

In approaching the CCJ we used the technique described by Kassam et al.⁴, albeit with some modifications. These include: a midline linear incision of the nasopharyngeal mucosa rather than the creation of a flap, the non-opening of the sphenoid sinus and the attempt to preserve the anterior C1 arch continuity working above and below it. Furthermore, for fractures, we always tried to fix the fracture by screws and plates, even in a narrow space, and filling the gap by autologous bone and/or bone substitutes to guarantee the better future arthrodesis.

In the present series, in 8 patients we were able to preserve the anterior C1 arch, while in 2 cases we reconstructed it. In our experience and according to the literature, anterior C1 arch preservation plays an important role for the biomechanical stability of the CCJ, as it could avoid two dreadful conditions: the phenomenon of cranial settling and the need for a posterior occipitocervical or C1-C2 fixation, with its related risk of subaxial subluxation development^{7 8 11 12 14}. On the contrary, in the transoral approach, for the angled working corridor, the anterior ring of C1 and the base of the odontoid process are almost always completely resected as well as in the transcervical approach, where C1 ring removal is essential to gain access to the lower clivus³. The last controversial issue

is represented by literature reports that describe the risk of spine instability secondary to disruption of craniocervical junction ligamentous attachments, even in case of bony preservation (i.e. anterior C1 arch). So far, all our cases did not present such complications even in the long term¹¹⁻¹⁴. We can hypothesise on some possible explanations based on our experience and literature evidence. Atlas ring integrity could prevent C1-C2 subluxation even in cases of transverse ligament disruption thanks to the important role of second stabilisers (capsular ligaments, paraspinal muscle, tectorial membrane, anterior longitudinal ligament, and ligamentum flavum) that provide a relevant restraint to C1-C2 segment motion²⁸⁻³⁴. Furthermore, analysing our cases of rheumatoid arthritis we found that in many cases, because of the inflammatory process of the synovial capsule and joints, the articulation between C0-C1 and C1-C2 already present some grade of fusion that limits movement and dislocations. Moreover, in most cases, in order to spare the anterior C1 arch, we do not remove the base of the odontoid process but only the dislocated tip to relieve brainstem compression. In these cases, the transverse ligament with its attachment to the bone, most likely, is almost entirely preserved and we noted after a few months a sort of fusion between the residual odontoid process and the posterior border of the C1 arch. Keeping this concept in mind, in the last cases we intentionally fused C1 to the residual C2 dens by screws and bone substitutes to enhance future spinal stability. Finally, management of odontoid and atlas fractures is still a matter of debate. Stable atlas fractures are treated conservatively, while unstable ones are surgically managed, usually by posterior occipito-cervical or C1-C2 fixations²⁹⁻³⁴. These procedures provide CCJ stability, but their serious disadvantage are the elimination of the rotational mobility at C1-C2 segment and the abolition of flexion-extension movement at C0-C1, resulting in an increased risk of lower cervical spine degeneration and instability²⁹. As demonstrated in two of our cases of odontoid fracture, a possible minimally-invasive alternative to posterior approaches is represented by the combined approach through the classic anterior cervical screwing supplemented by an EEA to clean up the bony borders, put bone chips in between to enhance the future arthrodesis and eventually reinforce the stability by C1 to C2 screws. All patients submitted to this combined approach presented radiologic evidence of fusion of the bone segments at follow-up without any clinical and radiological evidence of cervical instability. This is, in our opinion, the key point because the arthrodesis is the most important objective of the surgeon in these situations. This is without doubt obtained thanks to the direct contact between surfaces of the bony fragments and the bone chips that in the fracture gap replace the pseudoarthrosic tissue. The importance of C1-ring reconstruction, even after an anterior transoral or transcervical approach, was recently

stressed by other authors to restore CCJ stability with motion preservation^{28 31 40 41}. Pure endoscopic endonasal anterior C1 arch reconstruction could represent an innovative and function preserving option in the surgical treatment of atlas fractures. In our opinion, this approach is really minimally-invasive from an anatomical point of view, and considering patient discomfort provides the shortest way to the target and offers the best working angle with the possibility to gain a bilateral control of the entire anterior C1 arch. In all patients treated for post-traumatic atlantoaxial disease, neck pain quickly disappeared, no major complications occurred and oral feeding was re-started the day after surgery. At the last follow-up, the range of motion of the cervical spine was only slightly reduced (15% in rotation) and CT demonstrated the anterior C1 arch reconstruction with arthrodesis and anterior atlanto-occipital fusion between the atlas and lower clivus that further reinforces spine stability. Posterior occipito-cervical or C1-C2 fixation was not required.

Conclusions

An EEA may represent an innovative and complementary option for treatment of complex anteromedial located CCJ lesions, avoiding many of the morbidities associated with the transoral or transcervical approaches, resulting, in a safe, effective and well tolerated procedure. EEA allowed, in properly selected patients, preservation of the anterior C1 arch and avoidance of posterior fixation, thus preserving the rotational movement at C0-C2 segment and reducing the risk of development of subaxial instability. The main limitation of this approach consists of the narrow and deep surgical corridor; thus, these procedures should be performed only in selected centres by a multidisciplinary team that is well trained in endoscopic techniques. Obviously, long-term clinical studies will be needed to better understand the indications, clinical advantages and disadvantages of this technique.

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