Craniovertebral Junction Transanasal and Transoral Approaches: Reconstruct the Surgical Pathways with Soft or Hard Tissue Endocopic Lines? This Is the Question

Massimiliano Visocchi, Giuseppe Barbagallo, Vincenzo Lorenzo Pascali, Pierpaolo Mattogno, Francesco Signorelli, Gerardo Iacopino, Antonino Germano', and Giuseppe La Rocca

Abstract A variety of pathological conditions may affect the clivus and the craniovertebral junction (CVJ). These include congenital disorders, chronic inflammation, neoplasms, infections, and posttraumatic conditions that could all result in CVJ compression and myelopathy Endoscopic-assisted procedures have been further developed for CVJ decompression and they have now become conventional approaches. The aims of the present study were:

(1) to compare "radiological" and "surgical" nasoaxial lines (NAxLs); (2) to introduce an analogous radiological line as a predictor of the superior extension of the transoral approach (palatine inferior dental arch line (PIA); (3) to compare the "radiological" nasopalatine line (NPL) with the "surgical" NPL (SNPL) and surgical PIA (SPIA); (4) to compare "our" SNPL with the NAxL; and (5) to find possible radiological reference points to predict, preoperatively, the maximal extent of superior dissection for the transoral approach (SPIA).

Keywords Endoscopy • Transnasal approach • Transoral approach • Craniovertebral junction

M. Visocchi, MD • M. Pierpaolo, MD
S. Francesco, MD • G. La Rocca, MD (✉)
Insitute of Neurosurgery, Medical School,
Catholic University of Rome, Rome, Italy
e-mail: giularocca86@gmail.com

G. Barbagallo
Division of Neurosurgery, Department of Neurosciences,
Policlinico "G. Rodolico" University Hospital, Catania, Italy

V.L. Pascali
Department of Public Health, Institute of Legal Medicine,
Catholic University of Rome, Rome, Italy

G. Iacopino, MD
Department of Experimental Biomedicine and Clinical
Neurosciences, School of Medicine, Neurosurgical Clinic,
University of Palermo, Palermo, Italy

A. Germano', MD
Department of Biomedical Sciences, Neurosurgery,
University of Messina, Messina, Italy

Introduction

A variety of pathological conditions may affect the clivus and the craniovertebral junction (CVJ). These include congenital disorders, chronic inflammation, neoplasms, infections, and posttraumatic conditions that could all result in CVJ compression and myelopathy. Fang and Ong, in 1962, performed transoral decompression for irreducible atlantoaxial abnormalities in the first series of patients who underwent this procedure [1]. The microsurgical ventral approach to the CVJ has since been widely described for the decompression of irreducible extradural pathology [2–5] and was popularized by Crockard to drain retropharyngeal abscesses [1, 3]. Endoscopic-assisted procedures have been further developed for CVJ decompression and they have now become conventional approaches [4, 6–8]. Kassam et al. introduced the fully endoscopic transnasal approach to the CVJ [9, 10] and emphasized a nasopalatine line (NPL) as a reliable predictor of the maximal extent of inferior dissection. According to these authors the line created by connecting the most inferior point on the nasal bone to the most posterior point on the hard palate in the midsagittal radiological plane was found to be the best way to predict the real surgical lines. Many experimental studies have been performed to test the feasibility of the endoscopic transnasal approach, as well as to compare microsurgical and endoscopic transoral approaches [6, 8, 9]. We have performed neuroradiological studies to compare transnasal and transoral surgical domains: we evaluated, in cadavers, the surgical exposition angle and the working channel volume of both the transnasal and transoral approaches, employing a procedure with open mouth, with an oral distractor [10].

A novel radiological and surgical nasoaxial line (NAxL) was conceived in order to overcome the unreliability of the NPL, this being due to the resistance of the skin of the nose [11–13] (Fig. 1). We note that, so far, no conceptually analogous radiological line has been introduced as a reliable predictor of the maximal superior extension of the transoral approach.

M. Visocchi et al. (eds.), *Trends in Reconstructive Neurosurgery*, Acta Neurochirurgica Supplement 124,
DOI 10.1007/978-3-319-39546-3_18,

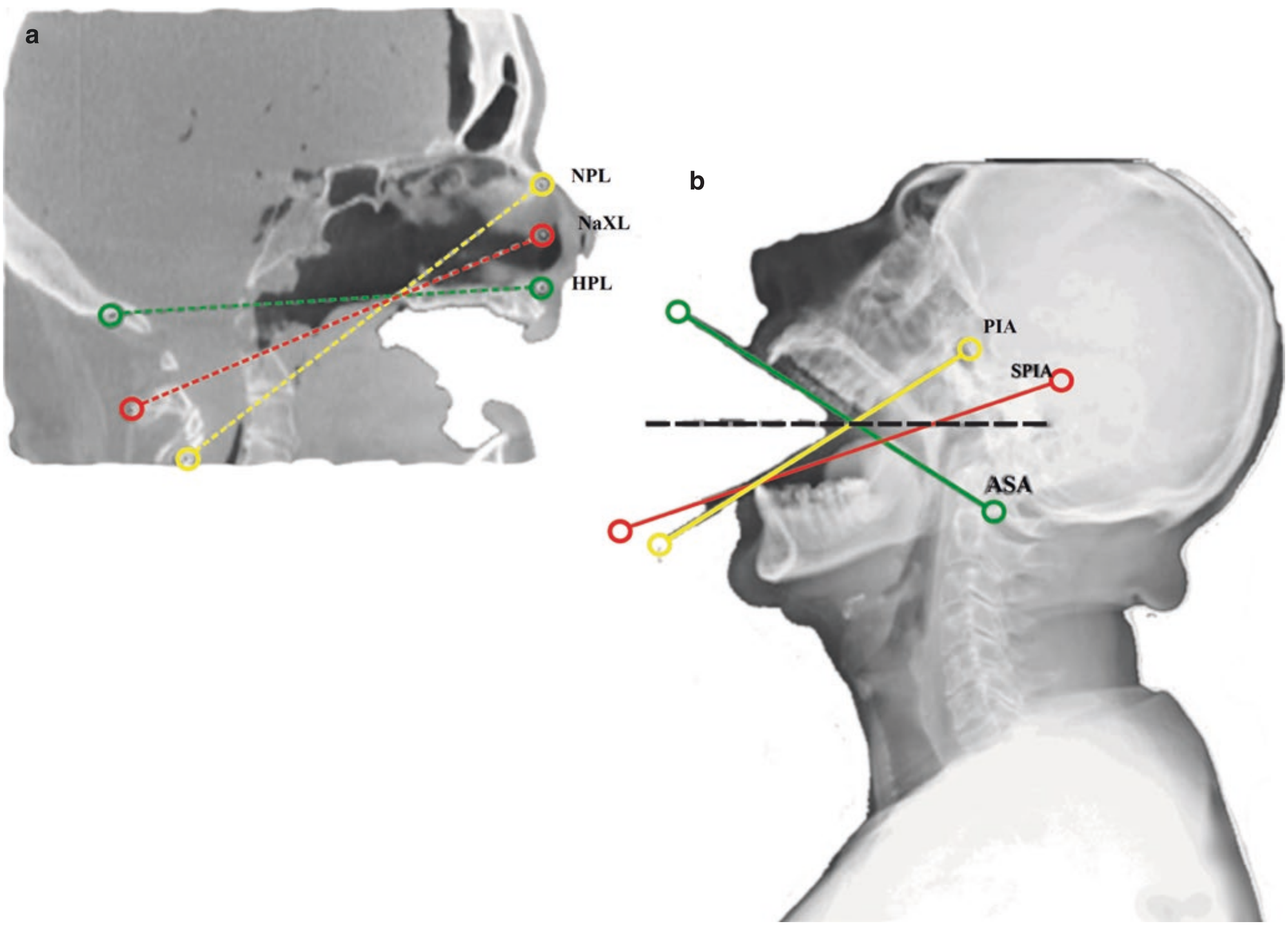

Fig. 1 (**a**) Comparison of the nasoaxial line (*red*) and nasopalatine line (*yellow*) with the actual surgical extent. The NAxL closely corresponds to the lowest limit of the endoscopic endonasal approach to the craniovertebral junction; the NPL overestimates the prediction on preoperative images. *NAxL* nasoaxial line, *NPL* nasopalatine line, *EEA* endoscopic endonasal approach, *HPL* hard palate line. (**b**) Lateral open-mouth skull X-ray with palatine inferior dental arch line (PIA; *continuous line*), atlanto superior dental arch line (ASA; *continuous line*), and surgical PIA (SPIA; *red line*). The SPIA was found to be engaged at the soft palate with the line in the midsagittal plane that crosses, at the midpoint, two more lines: the radiological PIA (RPIA) and ASA; these are defined as the line (*dotted line*) joining the superior dental arch and the anterior base of the atlas (see text)

The aims of the present study were:

1. to compare radiological and surgical NAxLs;
2. to introduce an analogous radiological line as a predictor of the superior extension of the transoral approach (palatine inferior dental arch line [PIA]);
3. to compare radiological with surgical NPL (SNPL) and surgical PIA (SPIA);
4. to compare "our" SNPL with the NAxL;
5. to find possible radiological reference points to predict preoperatively the maximal extent of superior dissection for the transoral approach (SPIA).

Material and Methods

With Ethics Committee Approval of the experimental protocol granted by the Catholic University of Rome, Italy (protocol number P663/CE/2010 approved on July 28, 2010; subsequent amendment number P437/CE 2012 approved on May 2, 2012) we studied nine fresh nonperfused cadavers—five female and five male—median age 72 years (interquartile range 33; minimum 41, maximum 94), at the CVJ Surgery Research Center in the Department of Public Health, Institute of Legal Medicine, of our University. With the cadaver in the supine position with the head slightly extended (about 25°), a Crockard transoral distractor (Crockard Transoral Instrument Set; Codman and Shurtleff, Raynham, MA, USA) was placed in the oral cavity to expose the CVJ. The C1 tubercle was identified with the finger in all the cadavers and the position of the distractor was chosen according to fluoroscopic assessment (MPX+ portable X-ray unit; Philips Healthcare, Best, The Netherlands). We considered the NPL according to the Kassam definition and conceived a new PIA line from the inferior dental arch up to the hard palate, for preoperative transoral approach planning [11]. The radiological NPL and PIA lines were evaluated by means of X-ray and computed tomography (CT) scan (GE

LightSpeed VCT 64 Slice, 1.25 mm thin; General Electric, Milwaukee, WI, USA). Subsequently two thin stainless probes mimicking the endoscopic tools (30 cm length) were inserted through the nostrils (choanae) and the oral cavity, as exposed by the Crockard distractor. The SNPL and SPIA were then radiologically evaluated and compared more as usually [10, 11]. In detail the values of the angular (°) exposure of the transoral and the transnasal approaches, in reference to the hard palate line first described by Aldane [13], were evaluated for each subject by lateral reconstructions (Fig. 1). Percentage differences (%) between the radiological and surgical NPLs were evaluated, along with the radiological and surgical NPL ratio.

The same procedure was used for determining radiological and surgical PIA values. Box plot minimum-maximum values of the NPL and PIA are reported in Tables 1a and 1b. Furthermore, we also evaluated the NAxL and compared it with the SNPL [12].

No platybasia or basilar invagination was identified radiologically, nor was jaw-opening impairment found in any of the cadavers. The collected data were statistically analyzed. A descriptive analysis of the sample was carried out by means of median, interquartile range (IQR), and range for continuous variables, and absolute and relative frequencies for qualitative variables. In order to find statistically significant differences between the two surgical approaches, we performed a Wilcoxon signed rank test. We chose to use a nonparametric test because data were not normally distributed, as demonstrated by the Shapiro-Wilk test [15]. The analysis was performed using SPSS software version 12.0 for Windows and the statistical significance level was set at $P = .05$.

Results (Tables 1a and 1b; Fig. 1)

X-ray and CT scan measurements of the CVJ were performed in all the subjects. Statistically significant differences ($P = 0.05$) were found between the radiological (minimum 33°, maximum 41°) and surgical (minimum 22°, maximum 27°) NPLs and the radiological (minimum 36°, maximum 59°) and surgical (minimum 29°, maximum 49°) PIA angle values. The results of the study are summarized in Tables 1a and 1b. In all the cadavers the angular gap between the radiological and surgical lines was wider for the transnasal than for the transoral approach. The most reliable radiological preoperative line was found to be the PIA, with a mean ratio between the radiological PIA and surgical PIA of 0.82. On the other hand, the mean ratio between the radiological and surgical NPL was found to be only 0.66; in this case the differences were statistically significant (Fig. 1).

Moreover, we found a 100 % correspondence between the NAxL and the SNPL (NAxL/SNPL = 1) and finally we were able to identify the SPIA radiologically.

The SPIA was found to be the line, in the midsagittal plane, that crosses, in the midpoint, two more lines: the radiological PIA (RPIA) and the atlanto superior dental arch line (ASA), defined as the line joining the superior dental arch and the anterior base of the atlas (Fig. 1). We defined

Table 1a Angles of transnasal and transoral radiological and surgical routes

	Mean angle (°)
RNPL	36.4°
SNPL	24°
RNPL/SNPL	0.66
NAxL/SNPL	1
RPIA	47.2°
SPIA	38.9°
RPIA/SPIA	0.82

RNPL radiological nasopalatine line, *SNPL* surgical nasopalatine line, *NAxL* nasoaxial line, *RPIA* radiological palatine inferior dental arch line, *SPIA* surgical palatine inferior dental arch line.

Table 1b Medians and statistical analysis of radiological and surgical transnasal and transoral routes

Variable	Median (IQ range)	Wilcoxon signed-rank test (*P*)
RNPL	37.45° (3.57)	$P = 0.05$
SNPL	24.75° (3.07)	
RPIA	47.60° (4.83)	$P = 0.05$
SPIA	38.25° (3.38)	

IQ interquartile, *RNPL* radiological nasopalatine line, *SNPL* surgical nasopalatine line, *RPIA* radiological palatine inferior dental arch line, *SPIA* surgical palatine inferior dental arch line the NPL and the PIA as *"hard-tissue lines",* since they both deal with bone tissue only; we defined the NAxL (i.e., SNPL) and SPIA as *"soft-tissue lines",* due to their relationship with soft tissues such as the skin and the soft palate.

Discussion

The transoral-transpharyngeal approach provides surgical access to the anterior clivus, C1, and C2. However, the use of microscopes, high-speed drills, self-retaining mouth retractors, flexible oral endotracheal tubes, intraoperative neuroradiological investigations, neuronavigation, and electrophysiological monitoring has made transoral procedures much safer than they were previously [4, 15, 17, 18]. The 30° endoscope has been proposed for the transoral approach to avoid full soft-palate splitting, hard-palate splitting, or extended maxillo/mandibulotomy [19, 20]. Using the endoscope, the operator is able to look in all directions by rotating the instrument. The last high-profile cadaveric study recently available in the literature is the one by Pillai et al. [15], which quantified the surgical volume gained by the endoscopic approach: the surgical area exposed over the posterior pharyngeal wall was significantly improved using an endoscope (606.5–127.4 mm^3) compared with the finding with an operating microscope (425.7–100.8 mm^3), without any compromise of surgical freedom ($P = 0.05$). The extent of the clivus exposed with the endoscope (9.5 ± 0.7 mm) without splitting the soft palate was significantly improved compared with that associated with the microscopic approach (2.0 ± 0.4 mm) ($P = .05$) [15]. Some authors have reported anatomical studies and surgical experience with the endoscopic endonasal approach [8, 14]. In 2002, Alfieri et al. [21] were the first to perform a cadaveric study of totally transnasal endoscopic odontoidectomy through a one-or two-nostril route [12, 19]. Cavallo et al. [22] confirmed the observations of Alfieri et al. in a cadaveric study as, late on Messina et al. [14] and Kassam et al., in 2005, operated the first case through a fully transnasal endoscopic resection of the odontoid [8], [14] and concluded: "The transoral approach remains the 'gold standard'", but in contrast with this, "the defect created by transnasal approach is above the level of soft palate and should not be exposed to the same degree of bacterial contamination". Messina et al. [20], in further anatomical studies, concluded that, similar to the transoral approach, the endoscopic endonasal approach provides a direct route to the surgical target, but it seems to be related to lower morbidity. De Almeida et al. [12] published, in 2009, the concept of the NPL, a line created by connecting the most inferior point on the nasal bone to the most posterior point on the hard palate in the midsagittal plane, and they concluded that the NPL was a reliable predictor of the maximal extent of inferior dissection [16]. A novel line, the NAxL, used for the best preoperative planning to determine the inferior limit of the endonasal approach to the CVJ, has been identified as the line in the midsagittal plane that starts from the midpoint of the distance from the rhinion to the anterior nasal spine of the maxillary bone and ends at the C2 vertebra, tangential to the posterior nasal spine of the palatine bone.

Cadaveric Study

In our cadaveric study we showed a novel PIA and compared the surgical domains of the NPL and PIA. Radiological examination and comparison of both the transnasal and transoral CVJ sagittal surgical domains in the same subject by means of NPL and PIA allowed us to recognize which preoperative radiological planning might be more reliable and closer to the effective surgical route allowed. The cranial settling, CVJ kyphotic deformity, and other changes would alter the utility of the two approaches. In fact, it must be pointed out that we studied only "normal" subjects. We used the *classic* NPL and a *novel* PIA, i.e., *"hard-tissue lines",* as ideal reference points to compare the two surgical strategies. The transnasal approach is a viable strategy to reach the CVJ, but it has more limited angular (nostrils, choanae) and linear (NPL) surgical exposure, mainly related *to the stiffness of the skin of the nose,* which, in our view, makes it suitable only for certain types of diseases and prevents its systematic applicability in all other conditions, such as pathologies caudal to C2 (and obviously lateral tumors) [12, 23–26]. Moreover, although an obvious advantage of the transnasal approach is that there is no need to cut the soft palate (which minimizes potential postoperative morbidities such as swallowing disturbances and hypernasal speech, which are really limiting to quality of life if the palatine veil is lacking), the transoral approach provides better exposure of the CVJ, both on the sagittal plane and on the transverse plane, providing a larger working channel and allowing the easier handling of surgical instruments such as the endoscope [6]. With this tool, the advantage of soft palate-sparing might make the transnasal endoscopic approach less common than the transoral endoscopic-assisted one. However, we believe that the transnasal and transoral endoscopic procedures should not be considered in competition but as complementary approaches [11–13]. The present experience seems to emphasize that preoperative planning by means of *hard-tissue lines* seems to be closer to the surgical reality (i.e., *soft-tissue lines)* with the transoral approach compared with the transnasal, as demonstrated by the low radiological and surgical NPL ratio compared with the radiological and surgical PIA ratio.

Conclusions

1. The NAxL is confirmed to be a reliable preoperative predictor of the maximal extent of inferior dissection for the transnasal approach.
2. With the novel SPIA, it is possible to determine the maximal extent of superior dissection for the transoral approach with a simple lateral head X-ray examination with open mouth.
3. The NAxL/SNPL ratio appeared to vary more than the RPIA/SPIA and more than RNPL/SNPL (Table 1a).
4. There is 100 % correspondence between the NAxL and the SNPL;
5. *The SPIA was found to be the line, in the midsagittal plane, that crosses, in the midpoint, two more lines: the RPIA and the atlanto superior dental arch line (ASA), defined as the line joining the superior dental arch and the anterior base of the atlas* (Fig. 1b).

   In other words, both the soft-tissue lines vary from the hard-tissue lines, the but the NAxL varies more than the SPIA.

   The pros and cons of each approach have to be taken into account; as well, a combined transoral and transnasal approach may be chosen.

Conflict of Interest Statement The authors declare that they have not received any funds for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other foundation(s) requiring open access. Moreover, the authors declare that they have no personal or institutional financial interest in the drugs, materials, or devices described in their submissions.

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