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Rhinology

Type IV optic nerve and Onodi cell: is there a risk of injury during sphenoid sinus surgery?

Protrusione del nervo ottico di tipo IV all'interno della cellula di Onodi: quali rischi durante la chirurgia endoscopica sfenoidale?

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SUMMARY

Objective. This study aims to determine the prevalence and types of Onodi cell through computed tomography and investigate the relationship between Onodi cell and the surrounding structures, paying particular attention to the risky proximity to the optic nerve canal.

Methods. In this study, 430 computed tomography scans of paranasal sinuses were analysed to establish the prevalence and different types of Onodi cell. Furthermore, the relationship between Onodi cell and different patterns of sphenoid sinus pneumatisation and surrounding structures were investigated. Special attention was paid to the relationship between Onodi cell and the optic nerve canal, particularly in cases when the optic nerve canal was bulging by more than 50% into Onodi cell (Type IV).

Results. The Onodi cell was detected in 21.6% of cases, with the most common being Type I (48.5% right, 54.3% left). Type IV bulging of the optic nerve canal into the Onodi cell was observed in 47.1% of cases on the right side, 41.2% on the left side and bilateral in 11.7% of cases.

Conclusions. In our series, we observed a high prevalence of Type IV optic nerve bulging into the Onodi cell. For this reason, we suggest that clinicians should always try to identify it in a pre-operative setting with computed tomography to avoid catastrophic consequences during endoscopic sinus surgery approaching the sphenoid area.

KEY WORDS: Onodi cell, optic nerve, endoscopic sinus surgery, sphenoid sinus, computed tomography

RIASSUNTO

Obiettivo. *Questo studio ha lo scopo di determinare la prevalenza e le varie tipologie della cellula di Onodi attraverso lo studio delle immagini TC. Abbiamo inoltre analizzato le relazioni tra la cellula di Onodi e le eventuali strutture a rischio circostanti, ponendo particolare attenzione alla vicinanza con il nervo ottico.*

Metodi. *Sono state analizzate 430 scansioni di tomografia computerizzata al fine di determinare la prevalenza, la tipologia e i rapporti della cellula di Onodi con le strutture circostanti e con i diversi tipi di pneumatizzazione del seno sfenoidale. In particolare, è stato studiato il rapporto tra cellula di Onodi e il nervo ottico di Tipo IV (protrudente nella cellula di Onodi per più del 50% della sua circonferenza).*

Risultati. *La cellula di Onodi è stata riscontrata nel 21,6% dei casi. Il nervo ottico di tipo IV protrudente nella cellula di Onodi è stato individuato nel 47,1% dei casi a destra, nel 41,2% a sinistra e nell'11,7% dei casi bilateralmente.*

Conclusioni. *Nella nostra casistica abbiamo osservato un'alta incidenza di procidenza del nervo ottico (Tipo IV) nella cellula di Onodi, che per tale motivo dovrebbe essere sempre accuratamente valutata pre-operatoriamente in caso di interventi che prevedono un approccio chirurgico allo sfenoide, al fine di evitare gravi conseguenze iatrogene.*

PAROLE CHIAVE: *cellula di Onodi, nervo ottico, chirurgia endoscopica nasosinusale, seno sfenoidale, tomografia computerizzata*

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Introduction

Adolf Ónodi (1857-1919), professor of rhinolaryngology, described *cellula sphenoethmoidalis* (after that, known as "Onodi cell") in 1903 as a condition in which the most posterior or lateral ethmoid air cell extends posteriorly to lie lateral and/or superior to the sphenoid sinus (SS) [1].

Onodi cell (OC) are of particular interest during endoscopic sinus surgery (ESS) because of their close relationship with the optic nerve canal (ONC) and the internal carotid artery (ICA), making it crucial to examine computed tomography (CT) scans pre-operatively to avoid serious injuries [2-4].

Another reason why OC must be detected prior to surgery is because an OC often causes the natural ostium of the sphenoid sinus to be located more superiorly, and it is necessary for the surgeon to be aware of this anatomical variant when operating.

Multiple studies have demonstrated an increased prevalence of OC identification when examining CT scans on two to three axial planes [4-7].

Our study aims to investigate, through the analysis of 430 CT scans (860 slides), the prevalence and the patterns of OC and sphenoid sinus pneumatisation (SSP) and the relationship between OC and the ONC, with particular attention to its bulging into the OC as it represents a relevant risk factor for critical and potentially irreversible consequences during ESS.

Materials and methods

This is a retrospective study including the analyses of paranasal sinus CT scans images from of 430 patients, analysing a total of 860 sphenoidal sinuses), collected at a 1.5 mm slice thickness as part of the pre-surgical assessment for patients undergoing ESS for chronic rhinosinusitis. Patients were enrolled between November 2017 - December 2022 at "San Luigi Gonzaga" University Hospital. Inclusion criteria were individuals older than 18 with rhinonasal symptoms (nasal obstruction, chronic sinusitis, rhinorrhoea) undergoing sinus surgery for the first time. Patients with rhinonasal malignancies, facial bone fractures, previous head trauma and massive nasal polyposis that could modify normal anatomy were excluded.

High-resolution CT images were performed in three axial planes and without contrast medium, as is normally done in pre-operative assessment protocols. Images were reviewed and analysed independently by three sinus surgeons and two radiologists with extensive and long-standing sinus surgery experience using a commercially available software viewer (window OsiriX).

Based on CT scans, the following variables were assessed:

- sagittal, coronal, and axial planes of all analysed CT were used to identify the presence of OC and its localisation (right, left, or bilateral). OC was identified as ethmoidal cells extending posteriorly or laterally to the anterior wall of sphenoid sinus;
- according to Thimmaiah et al. [8], three patterns of OC pneumatisation were assessed: Type I (superior) if the sphenoethmoidal cell was located above and medial to the sphenoid sinus (Fig. 1), Type II (superolateral) if the air cell was located both above and below to a horizontal line drawn at the uppermost part of SS in a coronal plane (Fig. 2), and Type III (lateral) if sphenoethmoidal cell was located below the horizontal line (Fig. 3);
- the relationship between ONC and OC wall was evaluated according to the studies of Ozdemir et al. [2] and Chmielik et al. [2,4]. The grade of protrusion of ONC was calculated by measuring the diameter of the ONC on the axial and sagittal plane, focusing specifically on Type IV which defines ONC bulging into the OC by more than 5 mm or more than 50% of the circumference of the ONC in two planes (axial or sagittal plane). It is worth to note that this classification of types of ONC are defined only in relation to an OC, and not to any other cells or the sphenoid sinus;
- the presence of the ICA bulging into OC;

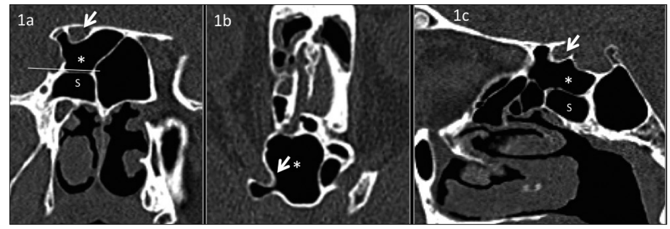

Figure 1. Onodi cell (*) Type I pattern of pneumatisation is above and medial the horizontal line. (**1a**) Coronal, (**1b**) Axial and (**1c**) Sagittal, paranasal CT scan. A horizontal line was drawn at the uppermost part of sphenoid sinus (s) in the coronal image (**1a**). Optic canals (white arrows) with bulging > 5 mm (Type IV) are shown.

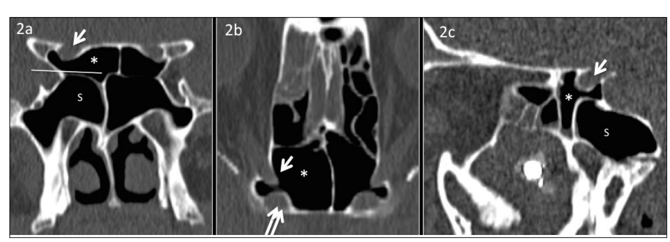

Figure 2. Onodi cell (*) Type II is above and below the horizontal line. Axial (**2b**) CT image showing protrusion of ICA (double arrow). (**2a**) Coronal, (**2b**) Axial and (**2c**) Sagittal, paranasal CT scan. A horizontal line was drawn at the uppermost part of sphenoid sinus (s) in the coronal image (**2a**). Optic canals (white arrows) with bulging > 5 mm (Type IV) are shown.

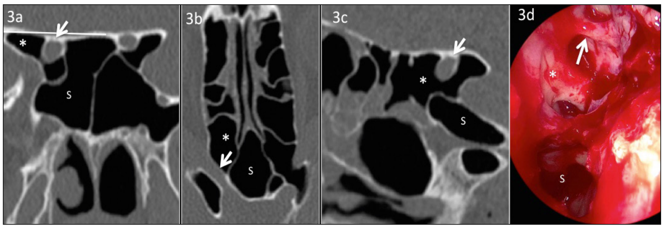

Figure 3. Onodi cell (*) Type III is below the horizontal line. (**3d**) Endoscopic right sphenoid sinus, Onodi cell and optic canal are showed. (**3a**) Coronal, (**3b**) Axial and (**3c**) Sagittal, paranasal CT scan. A horizontal line was drawn at the uppermost part of sphenoid sinus (s) in the coronal image (**3a**). Optic canals (white arrows) with bulging > 5 mm (Type IV) are shown.

- the relationship between OC and different patterns of SSP (sellar, presellar, conchal and postsellar type) was evaluated considering the location of posterior sinus wall concerning the position of the sella turcica on the sagittal plane [9].

Statistical analysis

The associations between variables of interest were evaluated using the Chi-square test. If the expected frequencies were less than 5 for more than 25% of the cells in the contingency tables, Fisher's exact test was performed. The analyses were conducted using SAS System 9.4 (SAS Inc, Cary, NC, USA).

Results

CT scans of 430 patients were analysed retrospectively (mean age 53 ± 18.9 years; range: 18-92 years. 57% of patients were male (n = 245) and 43% female (n = 185). OC was identified in 93 of 430 scans (21.6%). Of these, 35.5% were detected on the right side, 37.6% on the left side, and 26.9% were bilateral. Type I was the most prevalent, accounting for 16 scans (48.5%) on the right side, 19 (54.3%) on the left side, and 35 scans considering the totality of OC detected simultaneously on the right and left sides (Tab. I).
18.3% of cases presented a bulging of the ONC into the OC by more than 50% of the circumference (Type IV). Of these, 47.1% occurred on the right side, 41.2% on the left side and 11.7% (only 2 cases) on both left and right side. ICA protruded into the OC in 8 scans (8.6%). (Tab. I). The presence of OC was significantly associated with the presence of a Type IV-ONC for both sides (*p*-value < 0.0001). The presence of bilateral OCs also showed a statistically significant association with Type IV-ONC coexistence (*p*-value < 0.0001).
The association between the presence of Type IV-ONC and all the different types of OC was also investigated. Our re-

Table I. Relation between side and type of Onodi cell and bulging Type IV of the optic nerve canal on 430 PNSCT.

	N (%)	Men N (%)	Women N (%)	Bulging ONC (type IV)	Protrusion ICA
R-Onodi cell	**33 (35.5)**	**18 (29)**	**15 (48.4)**	**8 (47.1) (p-value < 0.0001)**	**3 (37.5)**
Type I	16 (48.5)	9 (50.0)	7 (46.7)	5 (62.5) (p-value < 0.0001)	2 (66.7)
Type II	11 (33.3)	6 (33.3)	5 (33.3)	2 (25.0) (p-value < 0.0001)	1 (33.3)
Type III	6 (18.2)	3 (16.7)	3 (20.0)	1 (12.5) (p-value < 0.001)	-
L-Onodi cell	**35 (37.6)**	**27 (43.5)**	**8 (25.8)**	**7 (41.2) (p-value < 0.0001)**	**3 (37.5)**
Type I	19 (54.3)	14 (51.9)	5 (62.5)	4 (57.1) (p-value < 0.0001)	2 (66.7)
Type II	9 (25.7)	7 (25.9)	2 (25)	3 (42.9) (p-value < 0.0001)	1 (33.3)
Type III	7 (20.0)	6 (22.2)	1 (12.5)	- (p-value = 0.59)	-
B-Onodi cell	**25 (26.9)**	**17 (27.5)**	**8 (25.8)**	**2 (11.7) (p-value < 0.0001)**	**2 (25.0)**
Total	**93/430 (21.6)**	**62/93 (66.7)**	**31/93 (33.3)**	**17/93 (18.3)**	**8/93 (8.6)**

ONC: optic nerve canal; R: right; L: left; B: bilateral; PNSCT: paranasal sinus CT.

sults demonstrated a significant association between the Type IV-ONC and all OC sub-types (p-value < 0.01) for both sides, except for Type III-OC on the left (p-value = 0.59).
Analysis of SSP associated to the presence of OC identified a predominance of the sellar type (60.6% on the right side, 65.7% on the left side), followed by the postsellar type (27.3% right and 20% left) and presellar type (12.1% right and 11% left) (Tab. II). Type I-OC was more represented among cases associated with the sellar type of SSP, both on the right side (9 cases) and on the contralateral side (14 cases). Only one case of Type I-OC was associated with the presence of the conchal type of SSP (left-sided).

Discussion

In the present investigation, we reported on the incidence of OC of 21.6%. Similar percentages were described by Ozturan et al. (16.6%) [10], while many previous studies showed extremely variable percentages ranging between 8% and 65% [3,11-19]. This inconsistency in prevalence of OC may be due to the different methods used for its identification (radiological *vs* anatomical). Tanaviratananich et al. [17] found a prevalence of 60% during studies conducted on cadavers, and similar results were reported in the works by Kantarci et al. (60%) [13] and Tomovic et al. (65.3%) [12]. Furthermore, many of the studies were carried out analysing only one [12] or two CT planes (axial and/or coronal). In our study, the identification of OC was performed on all three CT scan planes (coronal, axial and sagittal) to obtain a more accurate evaluation of this anatomical variant.

Regarding the prevalence of sub-types of OC, Thimmaiah et al. [8] described three main patterns of pneumatisation, with Type II being the most common, followed by Type I and Type III. In our study, Type I was the most common followed by Type II. Our percentages correlate with those found in the previous literature: in the study by Ali et al. [3], Type I was the most prevalent, while Chmielik et al. [4] reported that Type II was the most common pattern (Tab. III).
The improvement of systematic preoperative CT analysis to detect the presence of OC and their pattern of pneumatisation can decrease the risk of ONC injury during ESS, thus avoiding catastrophic consequences such as blindness [8]. Özdemir et al. [2] reported four types of relationships between the ONC and the OC, using the classification first described by Chmielik et al. in their study [4]. Type IV-ONC in relationship with the OC was described by some authors as the most dangerous pattern, as the potential risk during ESS is greater when more than 50% of the circumference of ONC is bulging into the OC [20]. We found 17 cases (18.3%) of ONC presenting a bulging into the OC of more than 50% (Type IV), representing a relevant risk factor for injury during ESS. The dangerous relationship between OC and ONC has been pointed out previously by several authors [2,4,11,12,21], but most considered the totality of ONC bulging, without differentiating those that protruded more than 50% (Type IV).
On the other hand, Yeoh et al. [20] found a prevalence of 51% of ONC protruding into the OC and concluded that the most dangerous type of ONC was the one with no bulging, because of the extremely thin wall separating the spheno-ethmoidal air cell and the ONC itself.

Table II. Relation between the type of Onodi cell and type of sphenoid sinus on 430 PNSCT.

	Sellar N (%)		Presellar N (%)		Conchal N (%)		Postsellar N (%)		Total
R-Onodi cell	**20/33 (60.6)**		**4/33 (12.1)**		**-**		**9/33 (27.3)**		**33/93 (35.5)**
Type I	9/20 (45.0)		2/4 (50.0)				5/9 (55.6)		
Type II	8/20 (40.0)		2/4 (50.0)				1/9 (11.1)		
Type III	3/20 (15.0)		-				3/9 (33.3)		
L-Onodi cell	**23/35 (65.7)**		**4/35 (11.4)**		**1/35 (2.9)**		**7/35 (20.0)**		**35/93 (37.6)**
Type I	14/23 (60.9)		3/4 (75.0)		1/1 (100.0)		1/7 (14.3)		
Type II	4/23 (17.4)		1/4 (25.0)		-		4/7 (57.1)		
Type III	5/23 (21.7)		-		-		2/7 (28.6)		
B-Onodi cell	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	
	13/25* (52.0)	**14/25*** (56.0)	**3/25*** (12.0)	**2/25*** (8.0)	**3/25*** (12.0)	**5/25*** (20.0)	**6/25*** (24.0)	**4/25*** (16.0)	**25*/93 (26.9)**
Type I	11/13 (84.6)	12/14 (85.7)	2/3 (66.7)	1/2 (50.0)	2/3 (66.7)	1/5 (20.0)	4/6 (66.7)	2/4 (50.0)	
Type II	2/13 (15.4)	-	1/3 (33.3)	1/2 (50.0)	-	4/5 (80.0)	-	2/4 (50.0)	
Type III	-	2/14 (14.3)	-	-	1/3 (33.3)	-	2/6 (33.3)	-	
Total									**93/430 (21.6)**

PNSCT: paranasal sinus CT; PRP: pterygoid recess pneumatisation; SRP: sphenoidal rostrum pneumatisation; R: right; L: left; B: bilateral.
** (25*) This refers to the total number of patients with bilateral OC (in total 50 OC in this group).*

Table III. Comparison of Onodi cell in the literature.

	No. PNSCT	No. PNSCT sides	No. OC (%)	No. R-side (%)	No. L-side (%)	No. Bilateral (%)	Bulging ONC (%)
Kasemsiri, 2011 [16]	187	374	92 (49.7)*	-	-	-	-
Shin, 2011 [14]	162	324	54 (33.3)	16 (29.6)	15 (27.8)	23 (42.6)	-
Tomovic, 2012 [12]	170	340	117 (68.8)	45 (38.5)	28 (23.9)	44 (37.6)	-
Ozturan, 2013 [10]	999	1998	160 (16.6)	58 (36.3)	50 (31.2)	52 (32.5)	80.1%
Wada, 2015 [18]	261	522	132 (50.6)*	-	-	-	34.8%
Senturk, 2017 [19]	618	1236	326 (52.7)	94 (28.8)	78 (23.9)	154 (47.3)	-
Chmielik, 2017 [4]	196	392	78 (39.8)	-	-	-	25%
Özdemir, 2019 [2]	508	1016	108 (21.2)	44 (40.7)	28 (25.9)	36 (33.4)	5.3%**
Thimmaiah, 2017 [8]	1080	2160	260 (24.1)	-	-	-	-
Ali, 2020 [3]	201	402	86 (42.8)	-	-	-	-
Fadda, 2022 [22]	430	860	93 (21.6)	33 (35.5)	35 (37.6)	25 (26.9)	18.3%**

*PNSCT: paranasal CT; OC: Onodi cell; ONC: optic nerve canal. * sides; ** only Type IV bulging.*

Another risk of injury during sphenoid sinus surgery is represented by the proximity of OC to the ICA. In this study, 8 cases were found (8.6%) where the ICA protruded into the OC, thus exposing the endoscopic procedure to the risk of a catastrophic haemorrhage. Ozturan et al. [10] reported an ICA protrusion rate of 2.8% in absence of an OC, but a prevalence of protruding ICA of 59% when the OC was present. They also concluded that increased dimension of OC significantly correlated with higher rates of protrusion of ICA. The relationship between different types of OC and different patterns of SSP were also evaluated. According to the Güldner classification [9], four types (sellar, presellar, conchal, and postsellar types) of SSP were considered. The sellar type was most commonly associated with the presence of OC, followed by the postsellar type. We did not find any similar correspondence in all previous analysed studies.

It is important to analyse CT scans before sinus surgery on all three axial planes, as stated before and based on evidence in literature. The sagittal plane is the most important for OC identification, since it provides information on the antero-posterior extension on the most posterior ethmoidal cell in relation to the sphenoid sinus.

Regarding complications during ESS in the presence of OC, in addition to accurate pre-operative review of the patient's surgical anatomy, the surgeon's experience and careful use of appropriate surgical instrumentation also play a key role in the successful management of potential iatrogenic injuries.

To minimise potential intra-operative injuries during sphenoid surgery in the presence of Type IV Optic Nerve into the OC, Fadda et al. [22] recommend using a neuroinvestigation system and to not use drills and surgical chisels to avoid injuries of vital structures, in particular when protruded ICA or ONC.

In addition, Humphreys et al. [23] reports use of through-cutting forceps instead of traction-instruments to remove bony partitions to avoid possible damage of vital neurovascular structures, to preserve the mucosal layer, and to reduce the risk of neo-osteogenesis and scarring. Shaver dissection along the sphenoid area should be carefully used to minimise the risk of dural violation and consequent brain injury. Strength and level of wall suction should be well regulated. Lastly, use of a neuroinvestigation system is also recommended similar to Fadda et al. [22].

Conclusions

The identification of OC and its relationship with adjacent structures in pre-operative assessment represents a prerogative of ESS because of its proximity to important anatomical structures such as the ONC and ICA. Its identification is crucial to avoid potential complications during surgery [11]. Furthermore, the presence of an OC, if not previously detected, can also be a source of a more difficult approach to the sphenoid sinus for the surgeon, since it may cause the natural ostium of the sphenoid sinus to be located more superiorly, and the asymmetry between sides may steer the surgeon in the wrong direction while opening the sinus. This anatomic variant can also cause difficulties in locating the skull base during trans-sphenoid exposure.

In the most challenging cases, given the risk by Type IV of ONC bulging into the OC, the use of the neuronavigation systems to assist the surgeon during ESS may be helpful to reduce the risk of complications; especially in cases where the widely enunciated risky variants of ONC may place the surgeon in a dangerous intra-operative setting, exposing the patient to potentially catastrophic consequences. Finally, in such cases, traumatic surgical tools such as drill or surgical chisel should be avoided when approaching the OC if the ONC is bulging into it (particularly in cases of Type IV-ONC).

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

GLF: substantial contributions to the work reported in this manuscript and surgeon, final approval of the version to be published; AU: substantial contributions to the conception or design of the work, final approval of the version to be published; AP: substantial contribution to the statistical analysis and interpretation of the data, final approval of the version to be published; MT, EdC, GC: substantial contributions to the preparation of patients undergoing surgery, editing, revision and final approval of the version to be published; LN, AMS, MP, DG: substantial contributions to the analysis of the CT scans, final approval of the version to be published.

Ethical consideration

This study was approved by the "San Luigi Gonzaga" University Hospital Ethics Committee (Date: 18.03.2022, protocol number: 4526). The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.

Written informed consent was obtained from each participant for study participation and data publication.

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