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Clinical Paper
TMJ Disorders

Temporal bone pneumatization in patients with dentofacial deformities: cone beam computed tomography study

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Abstract. Pneumatization in the osseous components of the temporomandibular joint (TMJ) may represent a complicating factor in TMJ surgery. This study determined the prevalence and characteristics of pneumatized articular eminence (PAE) and pneumatized glenoid fossa (PGF) using cone beam computed tomography (CBCT) scans of patients with and without dentofacial deformities. The CBCT of 587 asymptomatic patients (216 class I, 179 class II, 192 class III) were assessed to determine PAE and PGF. Age, sex, laterality, and type (uni/multilocular) of pneumatization were recorded. Differences were tested using the χ^2 test and binary logistic regression models ($P < 0.05$). Overall, 63.7% of patients presented some pneumatization: 15.5% presented both PAE and PGF, 0.9% presented only PAE, and 47.4% presented only PGF. The multilocular type was more frequent in both PAE and PGF ($P < 0.001$). There was a significant difference regarding dentofacial deformity for PAE ($P = 0.021$), with a higher frequency in class I. There were no differences according to sex, age, or laterality. The absence or lower frequency of pneumatization in class II and III patients may indicate continuous remodelling of the joint, which is submitted to abnormal occlusion forces. This knowledge is helpful for TMJ surgery planning, particularly as patients with dentofacial abnormalities may more often be candidates for TMJ surgery.

Key words: pneumatized articular eminence; pneumatized glenoid fossa; temporal bone; temporomandibular joint; cone beam computed tomography.

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Pneumatization is characterized by the presence of air-filled cavities and is commonly found at various sites of the skull. Pneumatization in the osseous components of the temporomandibular joint (TMJ) may facilitate the spread of fractures, inflammatory or neoplastic processes into the joint, since they represent sites of minimal resistance, and may represent a complicating factor in TMJ surgery[1]. Temporal bone pneumatization may affect the articular eminence (pneumatized articular eminence, PAE) and the glenoid fossa (pneumatized glenoid fossa, PGF)[1,2]. These alterations, which are clinically

asymptomatic, present as unilocular or multilocular radiolucent defects in the zygomatic process of the temporal bone, with a similar appearance to the mastoid or ethmoid cells, without destruction or enlargement of the cortex of the zygomatic bone[3].

In individuals with malocclusion (class II and III skeletal patterns), a significantly higher prevalence of degenerative joint disease and/or signs and symptoms of temporomandibular disorders (TMD) has been suggested[4,5], and TMJ surgery is more frequently indicated in these individuals[6]. The presence of temporal bone pneumatization in these patients may be a contraindication for surgical intervention[7], or at least alert the surgeon to the need for greater caution during the procedure.

Some previously published cases reports and prevalence studies of PAE have been based on panoramic radiographs[3,8,9]. However, other investigations have indicated cone beam computed tomography (CBCT) to be the method of choice for the assessment of the osseous components of the TMJ[4,10], since it is lower cost and has the advantage of a lower radiation dose when compared to helical CT. This high-resolution technology allows the visualization of bone components and air cavities without superimposition, exceeding the diagnostic accuracy of panoramic radiographs[1].

The aim of this study was to determine the prevalence and characteristics of PAE and PGF in asymptomatic patients regarding the dentofacial deformity, age, sex, laterality, and type of pneumatization, by means of CBCT.

Materials and methods

Ethical approval was obtained from the Ethics Committee in Research of the State University of Maringá, Brazil. This retrospective and observational study was developed according to the STROBE initiative[11].

Sample

The sample included CBCT scans of 587 asymptomatic patients (336 female (57.24%) and 251 male (42.76%)), who underwent examination for several reasons in the Oral Radiology Clinic (Laboratório de Imagens em Pesquisa Clínica, Universidade Estadual de Maringá) between February 2014 and July 2018. The patients were classified according to the Angle skeletal classification (A-point–nasion–B-point angle (ANB)) as follows: class I, $0° < ANB < 4°$ ($n = 216$); class II, $ANB \geq 4°$ ($n = 179$); class III, $ANB \leq 0°$ ($n = 192$)[12,13]. Each TMJ was considered individually, for a total of 1174 scans.

Patients with class II and III craniofacial deformities underwent CBCT before orthognathic surgery, with the objective of diagnosis and virtual surgical planning. Class I subjects were basically examined for reasons of diagnosis of oral or sinus pathologies and implant planning. The same radiologist performed all CBCT examinations and had full access to the patients' clinical records. All scans covered the articular eminence and the roof of the glenoid fossa bilaterally, in maximum intercuspation.

Exclusion criteria were patients with a history of a congenital craniofacial syndrome, dentofacial trauma, orthognathic surgery, TMD, orofacial pain, or mandibular dysfunction, and those with remarkable parafunction, rheumatoid arthritis, or other degenerative joint disease.

Images

The CBCT scans were obtained using a Next Generation i-Cat system (Imaging Sciences International, Hatfield, PA, USA), with settings of 120 kVp, 38 mA, 23 × 17 cm field of view (FOV), and a 0.3-mm isometric voxel size. Images were analyzed using the proprietary scanner software Xoran version 3.1.62 (Xoran Technologies, Ann Arbor, MI, USA), and the ANB angle measurements were performed in Dolphin Imaging 11.95 software (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). Before the angular measurements were obtained, a standardized orientation was achieved by rotating the volume to align the Frankfort plane horizontally and both transporionic and midsagittal planes vertically[14] (Fig. 1).

Data analysis

The right and left TMJ of each patient were evaluated in reconstructed axial, coronal, and sagittal slices and the frequency of pneumatization was quantified at the articular eminence and roof of the glenoid fossa. The diagnosis of PAE was made only if the following characteristics were found in the image[3]: a radiolucent area in the zygomatic process of the temporal bone with an appearance similar to mastoid air cells, extending anteriorly as far as the articular eminence but not beyond the zygomaticotemporal suture, with no enlargement or cortical destruction of the zygoma. PGF was considered when the radiolucent defect was located in the roof of the glenoid fossa, above the condyle (Fig. 2).

The pneumatization was also classified as unilocular (a single radiolucent oval defect with well-defined borders) or multilocular (numerous radiolucent small cavities)[1] (Fig. 3). The alterations were further classified as unilateral or bilateral.

The examinations were assessed independently by two external observers (radiologists, both with 10 years of experience with CBCT, calibrated by evaluating 20% of the sample). When differences were found, consensus was reached with the help of a third blinded external observer. The assessments were performed in duplicate with a 1-month interval, and only 10 examinations were evaluated per day to avoid eye fatigue. The examiners were allowed to change the image brightness and contrast, to obtain ideal visual conditions for the diagnosis.

Statistical analysis

The frequency of PAE and PGF was correlated with sex, laterality, and the type of dentofacial deformity using the χ test. Statistical evaluation of the relative risk of the development of pneumatization in relation to age was estimated using binary logistic regression models. The kappa index was used to assess intra- and inter-observer agreement. The significance level was set at $P < 0.05$. All statistical procedures were computed with IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA).

Results

The kappa value for intra- and inter-observer agreement was perfect ($\kappa = 1.00$). Overall, 374 (63.7%) patients presented some pneumatization: 91 (15.5%) had pneumatization in both locations (PAE and PGF), five (0.9%) individuals presented only PAE, and 278 (47.4%) presented only PGF. In total, 96 (16.3%) individuals presented PAE and 369 (62.9%) presented PGF. Considering the TMJ, 625 (53.2%) joints presented pneumatization: PAE in 130 (11.1%) and PGF in 610 (52%).

Table 1 reports the prevalence, distribution of laterality, and type of pneumatization for both PGF and PAE. A unilateral/bilateral ratio of 0.5:1 was found for PGF and of 2:1 for PAE. The left TMJ was more affected: 1.6:1 for PGF and 1.4:1 for PAE. The multilocular type was also more frequent, with a multilocular/unilocular ratio of 13.2:1 for PGF and

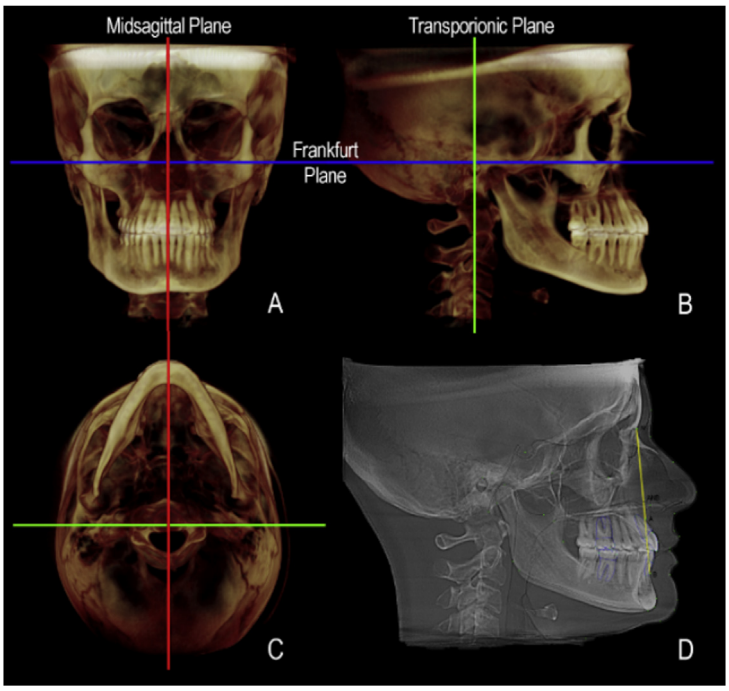

Fig. 1. Standardization of the CBCT scan before angular measurements: (A) alignment of the Frankfort horizontal and midsagittal planes on the frontal view; (B) alignment of the Frankfort horizontal and transporionic planes on the right view of the three-dimensional reconstruction; (C) alignment of the midsagittal and transporionic planes on the bottom view; (D) A-point–nasion–B-point angle (ANB) measurements analyzed in Dolphin software.

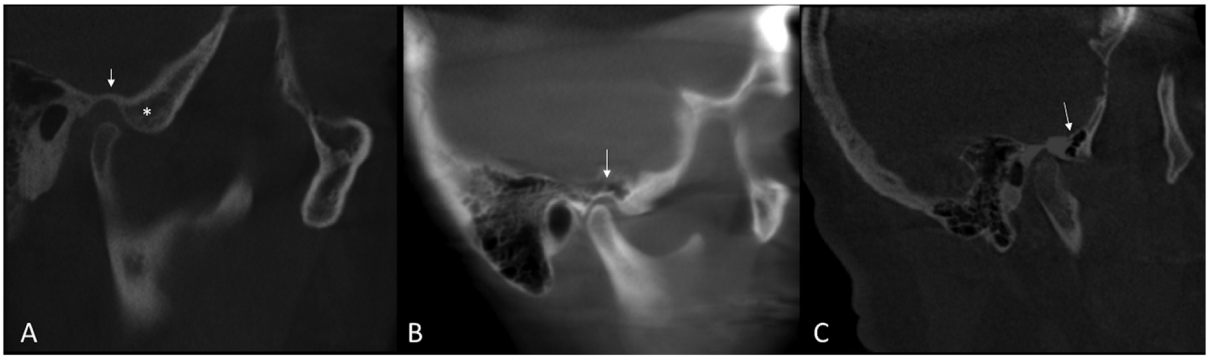

Fig. 2. Sagittal reconstructions: (A) absence of pneumatization in the articular eminence (*) and in the roof of the glenoid fossa (arrow); (B) pneumatization of the roof of the glenoid fossa (arrow); (C) pneumatization of the articular eminence (arrow).

7.7:1 for PAE. There was a statistically significant difference in the type of pneumatization for both PGF and PAE, with a higher frequency of the multilocular type ($P < 0.001$). However, there was no statistically significant difference with regard to laterality or localization ($P > 0.05$).

Although a higher female prevalence was found, with a sex ratio of 1.4:1 for PGF and 1.3:1 for PAE, the difference was not statistically significant ($P > 0.05$). However there was a statistically significant difference regarding dentofacial deformity for PAE ($P = 0.021$), with a higher frequency in the class I patients (Fig. 4).

The mean age of the individuals with pneumatization was 37.6 years. The youngest individual with pneumatization was a 10-year-old male with class I (PGF and PAE) and the oldest was a 91-year-old female with class I (PGF). The results of the binary logistic regression model showed no significant difference in the distribution of pneumatization according to age ($P > 0.05$) (Fig. 5).

Discussion

Although no treatment is necessary for pneumatization because it is asymptomatic[1], the presence of this condition has been considered a potential complicating factor for surgical procedures in the TMJ region[2,3,15]. Carter et al.[16] pointed out that an articular eminectomy is absolutely contraindicated in patients with a large degree of pneumatization. The air cavities represent areas of minimal resistance, facilitating the propagation of several pathologies into the joint such as fractures, neoplasms, and inflammatory processes[3]. A perforation through the bone defect during a surgical procedure, for example, might lead to dural tear and leakage of cerebrospinal fluid, resulting in intracranial haemorrhage or infection[15]. Fractures of the skull may extend through these cavities

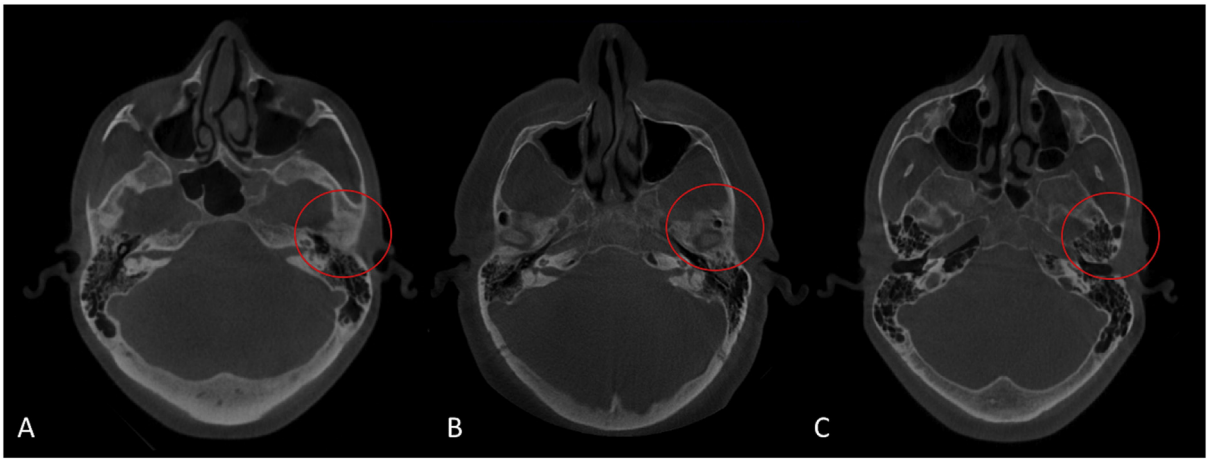

Fig. 3. Axial reconstructions: (A) absence of pneumatization (*); (B) unilocular and (C) multilocular types of pneumatization.

Table 1. Prevalence and distribution of pneumatization concerning type, localization, and laterality.

	Number	Pneumatized glenoid fossa		Pneumatized articular eminence	
		n	%	*n*	%
Patients	587	369	62.9	96	16.3
TMJ	1174	610	52	130	11.1
Laterality					
Unilateral		126	34.1	64	66.7
Bilateral		243	65.9	32	33.3
Unilateral cases					
Right		49	38.9	27	42.2
Left		77	61.1	37	57.8
Type					
Unilocular		43	7.0	15	11.5
Multilocular		567	93.0*	115	88.5*

TMJ, temporomandibular joint. *Statistically significant difference between multilocular and unilocular types ($P < 0.001$).

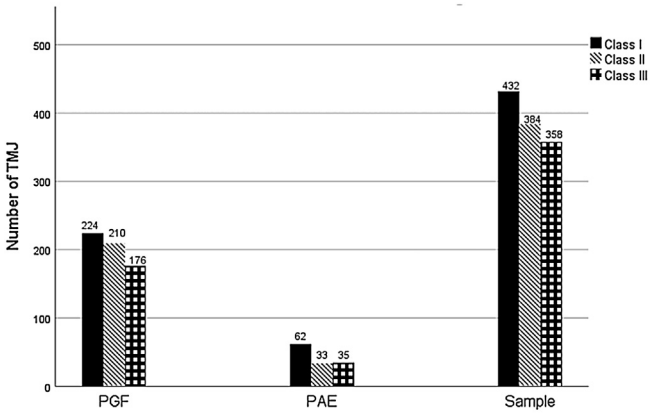

Fig. 4. Distribution of pneumatization according to facial pattern.

and release air into the glenoid fossa[2], and tumours and inflammatory processes of the ear and mastoid process may extend into the TMJ more easily and cause ankylosis[3]. Moreover, these changes may resemble certain pathologies such as giant cell and metastatic tumours, fibrous dysplasia, aneurysmal bone cyst, and haemangioma radiographically[3,6]. For this reason, several authors recommend that imaging studies should be performed prior to any procedure in the TMJ region[2,8].

In studies using panoramic radiographs, the prevalence of PAE has been reported to be between 1.0%[8] and 6.2%[17]. In CBCT studies[7,15,18,19], higher prevalence rates of 8%[7] to 76.7% have been reported[19]. In the present investigation, the prevalence of PAE was 16.3%, a rate similar to that found in a previous study of 21.3%[1]. Indeed, panoramic radiographs are considered the initial method for the evaluation of pneumatization due to the low radiation dose and cost[7]. As PAE is often an incidental finding in examinations performed for other objectives, the diagnosis is usually made through a panoramic image[20]. However, de Rezende Barbosa et al.[18] showed that the radiograph has medium to low accuracy for the diagnosis of temporal bone pneumatization when compared to CBCT. This imaging modality has no superimposition of structures, magnification or distortion[21], and its resolution allows air cavities as small as 2 mm to be differentiated from bone marrow[19]. Hence it is considered the gold standard imaging method for the evaluation of pneumatized air spaces of the skull[18].

Regarding PGF, this has only been assessed more recently, as this became possible with the advent of CBCT[1]. The accuracy of diagnosing PGF is very restricted when using radiographs[18]. Only one study has reported the prevalence of PGF (38.3%) in CBCT images[1]. A higher prevalence was found in the present study (62.9%), and it was also noted that 15.5% of the patients had pneumatization in both locations (PAE and PGF), while Ladeira et al.[1] detected both PAE and PGF in 20.4% of their sample. In fact, as demonstrated previously[1], PGF was much more prevalent than PAE in the present study (4.7:1) in all skeletal patterns. These data

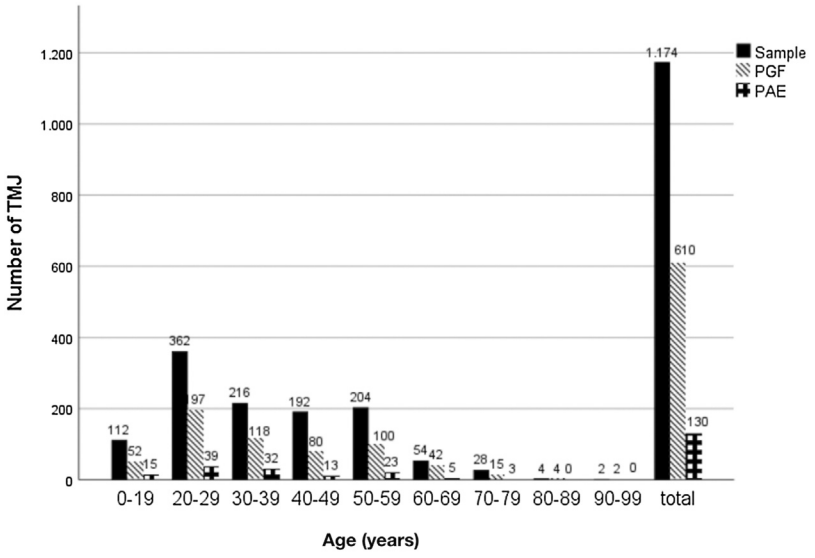

Fig. 5. Distribution of pneumatization according to age.

emphasize the importance of knowing that pneumatization may also occur in the glenoid fossa further on the articular eminence and presents the same clinical implications[1].

We agree with Ladeira et al.[1] that variations in the prevalence of temporal bone pneumatization may be due to ethnic differences in the patients studied. Additionally, technical parameters such as FOV, voxel size, artefacts, and the detector design may influence the image quality. For this reason the same acquisition protocol was used for all patients in the present study. Furthermore, no previous study has reported the influence of the dentofacial deformity on the results obtained. As demonstrated, the highest frequency of PAE was observed in the class I patients and this finding is unprecedented. For PGF, differences among classes were not statistically significant, although class I individuals were also more affected. It has been shown that the glenoid fossa significantly responds to environmental changes, such as the type and direction of the forces transferred to the TMJ[22]. In class I patients, there are no abnormal forces directed to the TMJ, hence bone remodelling is avoided and the dissemination of pneumatization is facilitated. However, this theory is speculative.

The influence of the malocclusion and dentofacial deformity on the relationship between the articular fossa and the condyle has been studied in recent years[4,5,22,23]. Based on the present study results, it is speculated that the absence or lower frequency of temporal bone pneumatization in class II and III patients may be related to ongoing remodelling and the adaptation process of the joint, which is submitted to abnormal occlusion forces. These unprecedented results are valuable since patients with dentofacial abnormalities may more often be candidates for TMJ surgery.

There was no statistically significant difference in skeletal group according to sex. These data are similar to the results of previous studies[1–3,15,19,24]. However, a distinct female preponderance was found for both PGF and PAE, corroborating other investigations[6,9,15]. Orhan et al.[6] explained that a possible reason for their finding of a higher prevalence of pneumatization in females was because pneumatization begins during maturation, and females who are chronologically older than males are also biologically further advanced. According to Khojastepour et al.[19], this phenomenon is not sex linked.

The mean age of patients with pneumatization was 37.6 years, similar to the mean age for PAE reported by Orhan et al.[9] (36.6 years), but lower than that reported by Kaugars et al.[8] (45.9 years) and Ladeira et al.[1] (41.7 years), and higher than that reported by Tyndall and Matteson[3] (32.5 years), Yavuz et al.[24] (30.0 years), Miloglu et al.[7] (30.6 years), and Khojastepour et al.[19] (30.31 years). The age range of patients with temporal bone pneumatization was wide (10–91 years), corroborating the findings of other authors[1,3,9,24]. It has been hypothesized that accessory air cell pneumatization starts after puberty[2], but, as has been found previously[1,9,19,24,25], pneumatization was detected in a class I patient before puberty (10-year-old male) in the present study.

No correlation was found between pneumatization and laterality, in agreement with other studies[6,9,19,25]. The literature shows that the ratio of bilateral to unilateral involvement is 1:2.5 in cases of temporal bone pneumatization. For PAE, we found that unilateral cases were more frequent, while a higher prevalence of bilateral cases was found for PGF. When PAE and PGF were evaluated together, Ladeira et al.[1] and Khojastepour et al.[19] found that bilateral cases were predominant. A brief review of the literature did not identify any study indicating a predisposing factor for pneumatization to be bilateral or unilateral, or any correlation of these data with the dentofacial deformity.

As found in some previous studies, a higher prevalence of the multilocular type of PAE[1,6,19] and PGF[1] was found in the present study; other authors have reported an equal distribution of multilocular and unilocular pneumatization[7,18]. We agree with Khojastepour et al.[19] that the higher incidence of the multilocular type may be related to the use of CBCT scans, which provide more accurate images, without distortion and/or superimposition of the anatomical structures. The majority of studies using panoramic radiographs presented limitations in the evaluation of the type of pneumatization[1]. Moreover, according to Tyndall and Matteson[3], the pneumatized articular eminence is contiguous with the mastoid process, in which the pneumatization is multilocular.

In conclusion, CBCT is a valuable tool to determine the type and localization of temporal bone pneumatization and its relationship to the adjacent tissues before any surgical intervention in the TMJ region. PGF was more prevalent than PAE, and a higher frequency of pneumatization was found in class I patients. Surgeons should be aware of these alterations, and this knowledge is helpful for image interpretation as part of surgical treatment planning for this maxillofacial region.

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Competing interests

All authors declare that they had no conflict of interest.

Ethical approval

This study was started after approval was obtained from the Ethics Committee in Re-

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Patient consent

Not required.

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