RESEARCH

Intracranial physiological calcifications evaluated with cone beam CT

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Objectives: The purpose of this study was to evaluate cone beam CT (CBCT) scans for the presence of physiological and pathological intracranial calcifications.

Methods: CBCT scans from male and female patients that met our ascertainment criteria were evaluated retrospectively ($n = 500$) for the presence of either physiological or pathological intracranial calcifications.

Results: Out of the 500 patients evaluated, 176 had evidence of intracranial physiological calcification (35.2% prevalence), and none had evidence of pathological calcification. There was a 3:2 male-to-female ratio and no ethnic predilection; the ages of affected patients ranged from 13 years to 82 years with a mean age of 52 years. The majority of calcifications appeared in the pineal/habenular region (80%), with some also appearing in the choroid plexus region bilaterally (12%), and a smaller subset appearing in the petroclinoid ligament region bilaterally (8%).

Conclusions: Intracranial physiological calcifications can be a common finding on CBCT scans, whereas pathological intracranial calcifications are rare.

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Keywords: cone beam computed tomography; intracranial calcifications

Introduction

Over the past several decades, the development of non-invasive advanced imaging techniques has allowed unparalleled display of the anatomical structures of the head and neck in healthy and diseased states. CT is useful for head and neck evaluation because of short imaging times, widespread availability and ease of access, fine resolution of bony detail and sensitive detection of intracranial calcifications.

Intracranial calcification can be physiological or pathological, often due to mineral (e.g. calcium) or metal (e.g. iron) deposition in the blood vessels, glands, cortices or other structures within the brain. CT is the most sensitive means of detecting intracranial calcifications. Physiological brain calcification is common and occurs in males and females at any age and of any ethnicity;

Daghighi et al¹ studied 1569 CT scans of patients ranging in age from 15 years to 85 years and a large percentage had physiological calcifications as follows: 71.0% had pineal gland calcifications, 66.2% had choroid plexus calcifications, 20.1% had habenular calcifications, 7.3% had tentorium cerebelli, sagittal sinus or falx cerebri calcifications, 6.6% had vessel calcifications, 0.8% had basal ganglia calcification and 0.9% had lens and other non-defined structure calcifications.

Conversely, pathological calcification in the brain has been described as a possible and extremely rare phenomenon in patients with (1) infectious diseases such as tuberculosis, toxoplasmosis or cysticercosis, (2) primary intracranial tumours or metastatic lesions, (3) autoimmune conditions such as lupus, (4) certain developmental disorders or syndromes, (5) endocrine disorders such as thyroid or parathyroid disease and (6) neuropsychiatric conditions associated with seizures or strokes.^{2–6} Table 1 summarises the causes of intracranial calcifications.

With the more common use of cone beam CT (CBCT) in dentistry, and with the advent of sensors that can display larger anatomical fields, the brain is an anatomical region that may be readily visualized on some CBCT

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Table 1 Aetiology of intracranial calcifications

Physiological calcifications	Pineal gland, choroid plexus, habenula, falx cerebri, tentorium cerebelli, petroclinoid ligament, sagittal sinus, dura mater
Developmental pathology	Gorlin syndrome, Sturge–Weber syndrome, haemangioma or arteriovenous malformations, Cockayne syndrome, neurofibromatosis, tuberous sclerosis, lipoma
Reactive pathology	Tuberculosis, cysticercosis, TORCH diseases, chronic viral encephalitis, Fahr disease, lupus, atherosclerosis, dystrophic calcifications, thyroid or parathyroid disease
Neoplastic pathology	Calcifying metastases, craniopharyngioma, chordoma, neurocytoma, ependymoma, meningioma, choroid plexus papilloma, medulloblastoma, germ cell tumours, primitive neuroectodermal tumour, ganglioglioma, astrocytoma, pinealoma/pinealblastoma, schwannoma, epidermoid/dermoid

TORCH, toxoplasmosis, other infections, rubella, cytomegalovirus, herpes simplex.

scans. Therefore, familiarity with intracranial findings such as physiological or pathological calcifications is important to our profession for diagnostic and medico-legal reasons.⁷ To our knowledge, there are no published studies evaluating CBCT for intracranial calcifications. Therefore, the purpose of this study was to evaluate CBCT scans for the presence of physiological and pathological calcifications in the brain.

Materials and methods

Appropriate institutional review board approval was obtained for this study (USC IRB #UP-11-00173). CBCT scans were randomly selected for retrospective evaluation and included male and female patients who were referred to the University of Southern California Ostrow School of Dentistry (Los Angeles, CA) or the Precision Ceramics Dental Laboratory (Montclair, CA) for scans related to dental implant treatment planning or orthodontic treatment planning, which are the most common reasons for CBCT scans in the dental patient population. Scans were performed with a 3M IMTEC ILUMA® Elite® scanner (3M IMTEC, Ardmore, OK), and ILUMAvision® software (3M IMTEC) with morphometric tools was used to evaluate and analyse the acquired DICOM (digital imaging and communications in medicine) files. For inclusion in the study, scans could represent patients of any age, sex or ethnicity. All scans had to be of adequate quality for evaluation and contain the entire brain within the field of image acquisition. Scans with artefacts such as motion artefact or metal artefact that superimposed any region of the brain were excluded from the study. 500 scans were selected that met all ascertainment criteria. Besides pooled demographic data (age/sex/ethnicity), which were analysed *post hoc*, no individual patient information, identifiers or medical history were available to the evaluating investigator (PPS) for the purposes of this study, to ensure blinding.

The ILUMAvision morphometric software was used to evaluate the size of the most common pineal/habenular calcifications. A measuring tool was used to assess the diameter of these calcifications when present, and these data were recorded in an SPSS® v. 20 (IBM Corporation, Armonk, NY) statistical software spreadsheet for subsequent analysis of means. Indistinct calcifications that could not be readily discerned from

background opacity and noise and those smaller than 1 mm in size were not counted as positive findings of calcification for the purposes of this study.

Results

We identified 176 patients out of 500 (35.2% prevalence) with intracranial physiological calcification and none with pathological calcification. There was a 3:2 male-to-female ratio in patients with physiological calcification and no ethnic predilection; their ages ranged from 13 years to 82 years with a mean age of 52 years. The majority of calcifications appeared in the pineal/habenular region (80%), with some also appearing in the choroid plexus region bilaterally (12%), and a smaller subset appearing in the petroclinoid ligament region bilaterally (8%). The calcifications that were identified in the pineal/habenular region appeared as single well-demarcated, amorphous or concentric, radio-opaque hyperdense masses. Morphometric analysis conducted to evaluate for size of these most common pineal/habenular calcifications revealed that they ranged in size from 1 mm to 7 mm in diameter, with a mean diameter of 4 mm. Calcifications appearing in the choroid plexus region were bilateral, round to curvilinear faint radio-opacities. Calcifications appearing in the petroclinoid ligament region were linear to curvilinear faint radio-opacities. Figure 1 demonstrates the characteristic radiographic appearance of physiological calcifications in affected patients compared with patients without calcification.

As is evident from Figure 1 and based on our results and experience, the appearance of calcifications on CBCT scans alone does not confirm location as it does in conventional CT, so it was impossible for us to definitively distinguish pineal from habenular calcifications, as their close anatomical proximity and the lack of detail of brain tissue anatomy precluded their discrimination. Therefore these regions were consolidated in our reporting.

Discussion

Although physiological calcifications in the brain are known by radiologists to be a relatively common incidental finding in advanced imaging studies, there

Figure 1 (a) Cone beam CT scan axial view of a 36-year-old male without evidence of brain calcifications as a negative control for comparison with images to follow. Note the lack of brain tissue detail and noise in this scan and scans to follow. (b) Sagittal view of a 16-year-old male with a small hyperdense mass (arrow) representing a typical midline brain calcification in the pineal/habenular region. (c) Axial view of a 76-year-old female with bilateral faint radio-opacities (arrows) representing petroclinoid ligament calcifications. (d) Axial view of a 56-year-old male demonstrating bilateral faint radio-opacities (arrows) that represent choroid plexus calcifications. Note the pineal/habenular calcification in the midline just medial and superior to these bilateral calcifications

are few published reports describing them, and none with respect to CBCT. In our study, we found a 35.2% prevalence of intracranial calcifications, mostly in the pineal/habenular region and with a characteristic appearance. Our findings are consistent with the current literature reporting that pineal calcifications are by far the most common intracranial calcifications,⁸ that they are found more commonly in males than in females⁹ and that pathological calcifications are extremely rare.⁴ The frequency of intracranial calcifications in our study is lower than in previous reports, probably because previous studies involved evaluation with medical CT rather than CBCT and the sensitivity/specificity for these devices differs for detection of such lesions, making direct comparisons inappropriate.^{1,10}

CT has better soft-tissue contrast and less noise than CBCT, allowing for better identification and

discrimination of lesions in the brain and their precise anatomical location compared with CBCT.¹⁰ Noise affects images produced by CBCT units by reducing low-contrast resolution, making it difficult to differentiate low-density tissues such as the soft tissues of the brain. There is very little noise in conventional CT because of the higher tube current used than in CBCT, and because of effective pre- and post-patient collimation, which reduces the scattered radiation to a negligible amount compared with CBCT, which has no post-patient collimation. Further, CBCT images and quality may vary based on type of scanner/hardware, software, patient factors, artefacts and sensor sizes, to name a few. The inherent limitations associated with CBCT compared with conventional CT accordingly affect image analysis and results, as we noticed in our study. It is likely that with conventional CT we could have detected a greater number of patients with

calcifications, and more subtle calcifications or calcifications in regions not currently identified. Therefore, CT remains the imaging modality of choice in the detection of intracranial calcification.^{11–13} A number of factors including slice thickness and window width and level may affect the detectability of calcification on CT.¹¹ Cost and use of ionizing radiation are considerations in choosing the most appropriate imaging procedure. In future, CT and MRI applications that concentrate on functional and physiological display of the central nervous system will add greatly to the clinical utility of these imaging tools.¹⁴

Our results suggest that CBCT scans can reveal intracranial calcifications, and thus the brain should be evaluated if it appears in CBCT volumes. It should be noted that there are limitations to our study, such as the use of one investigator to assess intracranial calcifications rather than multiple investigators. However, for the purposes of this study, and because of the nature of the data and the relative straightforwardness and ease of identifying calcification as present or not (thus providing for nominal data), we did not use multiple investigators or have the same investigator re-evaluate images in order to assess inter-rater or intrarater reliability statistically.

Finally, discriminating between physiological calcification and pathological calcification is important clinically, although pathological calcifications are rare. When they do occur, as a general guide pathological calcifications may appear larger than a few millimetres in size, or they may appear abnormal in shape and

configuration or non-symmetrical compared with physiological calcifications with irregular borders, or they may be located at sites other than those previously described as common for physiological calcification.^{2–4} In our study, the finding of small calcifications with well-defined borders, and symmetrical to the midline or bilateral, was highly indicative of a normal developmental or physiological process in these patients rather than representing pathological calcification; this along with the aforementioned factors should be kept in mind when trying to discriminate physiological from pathological calcifications in addition to any pertinent medical history or signs and symptoms clinically. Previous investigators have described pathological calcifications appearing on CT scans in significant detail for reference, but if questionable calcifications are discovered on CBCT scans by a non-radiologist practitioner, it may be prudent to seek the opinion of a maxillofacial radiologist for more accurate characterization and diagnosis, or for recommendation of additional imaging studies if warranted.¹⁰

In conclusion, our results indicate that intracranial physiological calcifications can be a common incidental finding on CBCT scans, whereas pathological intracranial calcifications are rare. Importantly, CBCT scans can have significant limitations for anatomical visualization and accurate identification and evaluation of intracranial calcifications compared with conventional CT, which remains more sensitive, specific and thus superior in this context.

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