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Mini Literature Review on the Classification of Intracranial Calcification and the Usefulness of Cone Beam Computed Tomography

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Abstract

Intracranial calcification has numerous radiographic and clinical presentations; therefore, classifications and the age of the patients are very important in the detection and diagnosis of the calcifications. Interestingly, cone beam computed tomography (CBCT) provides a useful imaging technique that is very crucial in the neuro-intervention regime; although, CBCT image is faced with some drawbacks such as poor soft tissue contrast, artifacts, and noise, however, these drawbacks are taken care of with the advent of improved techniques and software algorithms that improves signal-to-noise ratio contrast.

Keywords: CBCT, calcification, lesion, intracranial calcification

1.0 Introduction

Precision in radiological diagnosis plays a vital role in patients' detection and treatment planning (Evlice, 2017). Cone beam computed tomography (CBCT) is a renowned radiographic imaging technique that produces a three-dimensional (3D) image of hard tissues (Kumar et al., 2015; Mutalik & Tadinada, 2017; Spagnuolo, 2022) and has proven to be an important imaging technique that is vital in the neuro-intervention procedure (Dong et al., 2021; Jain et al., 2019).

Further, CB CT's invention aims to offset some of the limitations in conventional CT scanning devices such as improvement in high imaging resolution with excellent contrast visualization in vessels, soft tissues, and bone (Dong et al., 2021; Evlice, 2017). The advent of sensors with high anatomical display fields makes the brain an important anatomical region readily for visualization using CBCT scans (Bayrak et al., 2019; Nguyen & Enciso, 2012).

CBCT provides clear images with high-contrast structures and is an imaging technique suitable for craniofacial regions, that is extremely useful in the evaluation of bone and other hard tissues. Moreover, CBCT technological ingress in clinical practice creates several possible advantages for craniofacial imaging when compared to conventional CT (Scarfe et al., 2006).

Putting into account that CBCT has made speedy breakthroughs in the recent field of radiology, however, it is associated with some limitations which may be attributed to its projection geometry, contrast resolution, and detector sensitivity, further, CBCT image clarity is greatly affected by noise, poor soft tissue contrast, and artifacts (Venkatesh & Elleru, 2017; Scarfe et al., 2006). Nevertheless, efforts are being tilted towards developing software algorithms and techniques to improve contrast and signal-to-noise ratio (Scarfe et al., 2006).

Brain and intracranial calcification are common findings in radiographic techniques ranging from benign physiological calcification to severe pathological disorders that could lead to death (Daghighi et al., 2007; Grech et al., 2012). Intracranial calcifications result from the accumulation of calcium and iron in the blood vessels of different brain structures (Daghighi et al., 2007; Guedes et al., 2020), hence intracranial calcification is termed the calcification within the brain parenchyma or its vasculature (Al-Zaghal et al., 2019; Daghman & Bennour, 2020). Choroid plexus and pineal region calcifications are common intracranial calcification known to be present histologically from fetal life to adulthood (Al-Zaghal et al., 2019; Saade et al., 2020).

Conversely, it is a very difficult task to determine the specific cause of physiologically categorized intracranial calcification in patients due to age and other causes of calcification, however, understanding the anatomical location and morphology, dimension, distribution of the calcifications as well as age group and clinical history of the patient serves as important findings that can facilitate the differential diagnosis (Chattopadhyay et al., 2020; Guedes et al., 2020).

It is worth noting that due to the advent of some technological breakthroughs in recent decades, imaging modalities and methods have improved both in specificity and sensitivity of their assessment which assists in the diagnosis and reduces the possibility of precision errors (Evlice, 2017; Guedes et al., 2020; Nguyen & Enciso, 2012). This mini-review is aiming at highlighting the importance of cone beam computed tomography and classifying intracranial calcifications.

2.0 Classification of Intracranial Calcification

Intracranial calcifications are commonly found in non-contrast computed tomography scans in both adult and pediatric groups (Saade et al., 2020). Calcification of soft tissues in the maxillofacial region is a rare phenomenon that corresponds to findings in radiographic routine examinations such as panoramic radiographs (Altındağ et al., 2017). However, the calcification of soft tissues in the region of the head and neck can be categorized as physiologic or pathologic mineralization (Bayrak et al., 2019). Although, most of the structures in the head and neck are relatively close to each other making the localization and identification of these calcifications difficult (Altındağ et al., 2017; Price et al., 2012).

2.1 Physiological or Age-Related Calcification

Physiological or age-related calcification is associated with radiological findings in adults and elderly patients which can be found in the pineal gland, globus pallidus, choroid plexus, dura mater, habenula, petroclinoid ligament, tentorium, and cerebral sickle (Guedes et al., 2020). Further, pineal gland calcification is mostly seen in individuals more than 10 years of age with high prevalence, thus, globus pallidus calcification is seen in individuals more than 40 years of age (Guedes et al., 2020; Nguyen & Enciso, 2012).

The deposition of calcium in the brain parenchyma in the absence of any neurological or underlying pathologies is termed idiopathic calcification (Al-Zaghal et al., 2019), however, normal physiologic aging and neurodegenerative processes are thought to be related to idiopathic intracranial calcification (Daghighi et al., 2007).

2.2 Pathological Calcification

2.2.1 Metabolic and Endocrine Disorder Calcification

Disruption of calcium homeostasis could lead to brain calcification, these disorders include hyperthyroidism, hyperparathyroidism, and hyperparathyroidism, moreover, these diseases have overlapping radiological signs which make them difficult to differentiate visually due to their characterized bilateral, symmetric calcium deposition in different brain regions (Guedes et al., 2020; Saade et al., 2020).

2.2.2 Vascular Calcification

Vascular calcification (VC) is the pathological deposition of minerals in the vascular system which is attributed to degenerative disease affecting the wall of blood vessels (Wu et al., 2016). It could be due to the consequences of atherosclerosis, chronic kidney disease (CKD), diabetes, inflammatory disease, or aging with an increased risk of cardiovascular disease and mortality (Hénaut et al., 2015; Jono et al., 2006; Wu et al., 2016). Vascular calcification is age and gender-dependent with 90% of men and 67% of women older than the age of 70 years (Mohan et al., 2016).

Further, VC is clinically believed to be a result of the passive precipitation of minerals, however current clinical evidence established that VC results from an active and highly regulated cellular process similar to bone formation (Hénaut et al., 2015). Electron beam computed tomography (EBCT) examinations reveal that vascular calcification is very common among dialysis patients with coronary calcification scores of 2-5 times higher than non-CKD patients (Jono et al., 2006).

2.2.3 Infections Disease Calcification

Cryptococcus, cysticercosis, and tuberculosis are regarded as acquired intracranial infections naturally related to intracranial calcification, although calcification resulting from brain abscesses is particularly rare (Kim et al., 2013). Noteworthy, a brain abscess begins as a focal area of a localized area of cerebritis with pus collection surrounded by a vascular capsule which develops as a result of response to parenchymal infections due to bacterial infection (Gortvai et al., 1987; Rath et al., 2012).

2.2.4 Neoplastic Lesions Calcification

In the identification and evaluation of brain neoplasm, brain calcification plays a vital role hence, the presence or absence of calcifications along with the location of the tumor and the patient’s age assist in routine radiological identification of neoplasm (Saade et al., 2020). Neoplasm is classified into intra-axial (astrocytoma, oligodendroglioma, ganglioma, medulloblastoma, and metastatic lesions), extra-axial (meningioma, craniopharyngioma, pineal tumor, and germ cell tumor) and intraventricular which are commonly ependymomas, choroid plexus tumors and neurocytoma (Dinizio et al., 2016; Grech et al., 2012; Saade et al., 2020).

2.2.5 Non-neoplastic Expansive Lesions Calcification

Lesions such as epidermoid cysts, dermoid cysts, colloid cysts, and meningiomatosis are classified as non-neoplastic lesions that have an expansive character that can sometimes result in calcification (Guedes et al., 2020; Osborn & Preece, 2006).

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2.2.6 Neurocutaneous Lesions Calcification

Diseases that share signs of both cutaneous and neurological disorders often present with a distinct characteristic of calcifications (Guedes et al., 2020). These diseases include tuberous sclerosis, Gorlin-Goltz syndrome, Sturge-Weber syndrome, and neurofibromatosis (type I and II) which are definitive in diagnosis (Osborn & Preece, 2006; Umeoka et al., 2008).

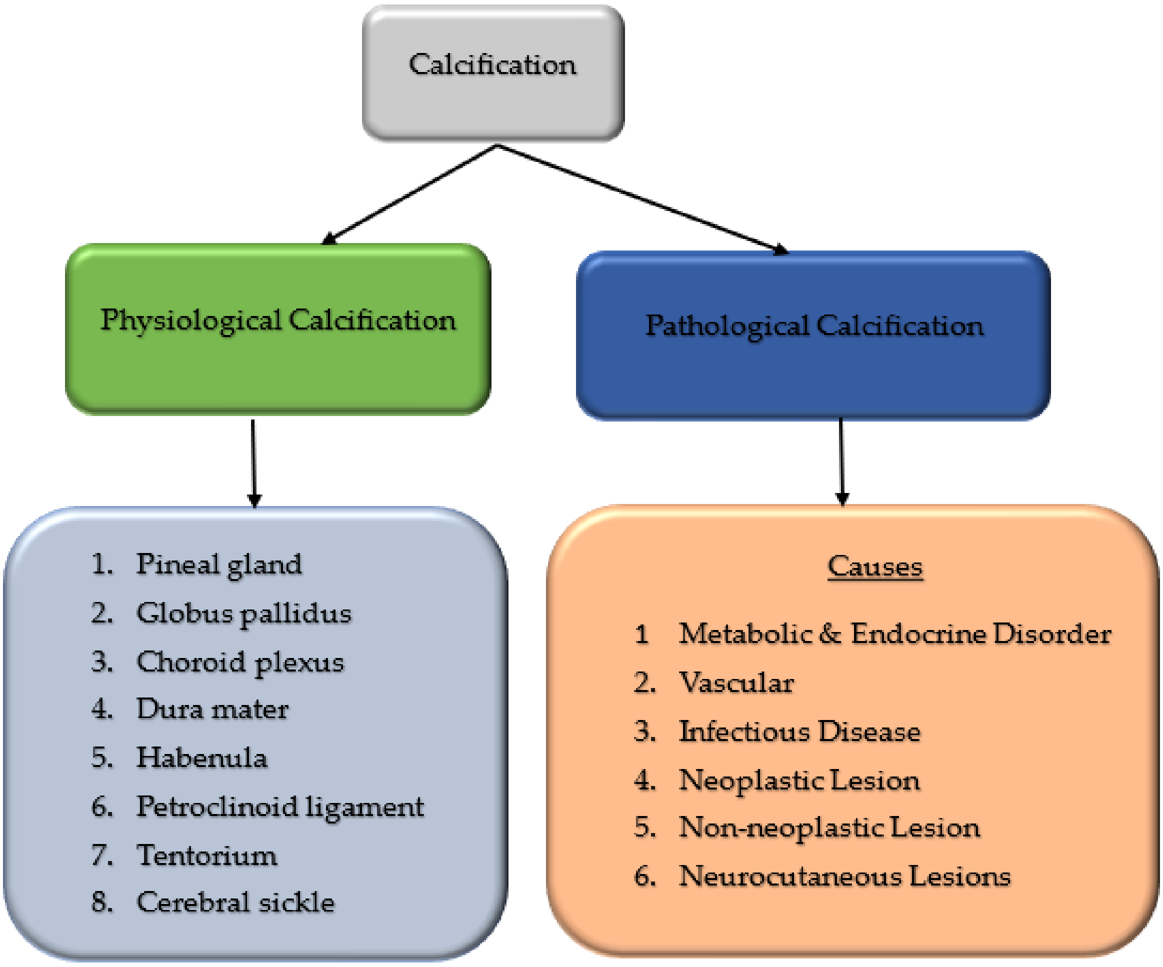

Figure 1: Schematic representation of a classification of calcification.

Clinical Significance of Intracranial Calcification

Intracranial calcification is an important biomarker in identifying atherosclerosis and understanding the severity of intracranial vascular disease (Wu et al., 2016). The leading cause of ischemic stroke nationwide is an intracranial atherosclerotic disease, accounting for about 30-50% of Asians and 10% of Caucasians (Yang et al., 2021).

In 2007, Cheng et al in their cross-sectional study reported an increase in the incidence of intracranial arterial calcification (IAC) among Chinese ischemic stroke patients(Chen et al., 2007), although, other studies indicated that IAC is not an independent predictor in recurrent stroke among Chinese patients and shows no significant correlation between IAC and post-stroke mortality (Li et al., 2023; Yang et al., 2021).

Interestingly, IAC is viewed as an incidental finding on some important imaging modalities on the brain such as CT and CBCT scans among the majority of the population, even though most of the calcification is seen as not a threat, but others can be associated with serious clinical consequences (Bartstra et al., 2020; van der Toorn et al., 2019).

Noteworthy, calcification has been restricted to arteries in population-based research associated with cardiovascular risk factors such as diabetics, hypertension, and smoking play a vital role in the manifestation of calcification in the aortic arch, coronary artery, external and internal carotid artery (van der Toorn et al., 2019).

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3.0 Conclusion

Intracranial calcification has a wide variety of clinical and radiographic manifestations with the classification and age of the patients playing a vital role in the identification and diagnosis of the calcification. CBCT has proven to be an important imaging technique that is vital in the neuro-intervention procedure. However, CBCT image precision is affected by noise, poor soft tissue contrast, and artifacts, although, these limitations are taken care of with efforts in developing software algorithms and techniques to improve contrast and signal-to-noise ratio.

References

1. Al-Zaghal, A., Seraj, S. M., Werner, T. J., Gerke, O., Høilund-Carlsen, P. F., & Alavi, A. (2019). Assessment of physiologic intracranial calcification in healthy adults using 18 F-NaF PET/CT. *Journal of Nuclear Medicine, 60*(2), 267–271. https://doi.org/10.2967/jnumed.118.213678
2. Altındağ, A., Avsever, H., Borahan, O., Akyol, M., & Orhan, K. (2017). Incidental findings in cone-beam computed tomographic images: Calcifications in head and neck region. *Balkan Journal of Dental Medicine*, *21*(3), 100–107. https://doi.org/10.1515/bjdm-2017-0015
3. Bartstra, J. W., van den Beukel, T. C., Van Hecke, W., Mali, W. P. T. M., Spiering, W., Koek, H. L., Hendrikse, J., de Jong, P. A., & den Harder, A. M. (2020). Intracranial Arterial Calcification: Prevalence, Risk Factors, and Consequences: JACC Review Topic of the Week. *Journal of the American College of Cardiology*, *76*(13), 1595–1604. https://doi.org/10.1016/j.jacc.2020.07.056
4. Bayrak, S., Bulut, D. G., Çakmak, E. Ş. K., & Orhan, K. (2019). Cone beam computed tomographic evaluation of intracranial physiologic calcifications. *Journal of Craniofacial Surgery*, *30*(2), 510–513. https://doi.org/10.1097/SCS.0000000000004918
5. Chattopadhyay A, Coates J, Craven I, et al. (2020). *Intracranial calcifications – a pictorial review.ECR 2018. [cited 2020 May 15]. Available from: https://epos.myesr.org/poster/esr/ecr2018/C-3273*. 3273.
6. Chen, X. Y., Lam, W. W. M., Ng, H. K., Fan, Y. H., & Wong, K. S. (2007). Intracranial artery calcification: A newly identified risk factor of ischemic stroke. *Journal of Neuroimaging*, *17*(4), 300–303. https://doi.org/10.1111/j.1552-6569.2007.00158.x
7. Daghighi, M. H., Rezaei, V., Zarrintan, S., & Pourfathi, H. (2007). Intracranial physiological calcifications in adults on computed tomography in Tabriz, Iran. *Folia Morphologica*, *66*(2), 115–119.
8. Daghman, A., & Bennour, A. (2020). Computed tomographic pattern of intracerebral calcifications in a radiology center in Benghazi, Libya. *Libyan International Medical University Journal*, *05*(02), 59–64. https://doi.org/10.4103/liuj.liuj_30_20
9. Dinizio, A., Vincent, J., & Nickerson, J. (2016). Intracranial Calcifications in the Pediatric Age Group: An Imaging Review. *Journal of Pediatric Neuroradiology*, *04*(03), 049–059. https://doi.org/10.1055/s-0036-1583312
10. Dong, J., Bai, X., Dmytriw, A. A., Xuan, L., Wang, T., & Lu, X. (2021). Identification of Carotid Artery Microstructure and Plaque Rupture Using C-Arm Cone-Beam CT : A Case Report. *Frontiers in Neurology*, *12*(December), 10–13. https://doi.org/10.3389/fneur.2021.801683
11. ELLURU, V. S. V. E. (2017). *S103. 51*, 102–121.
12. Evlice, U. T. and B. (2017). *Cone-Beam Computed Tomography for Oral and Maxillofacial Imaging*.
13. Gortvai, P., Louvois, J. De, & Hurley, R. (1987). The bacteriology and chemotherapy of acute pyogenic brain abscess. *British Journal of Neurosurgery*, *1*(2), 189–203. https://doi.org/10.3109/02688698709035304
14. Grech, R., Grech, S., & Mizzi, A. (2012). Intracranial calcifications: A pictorial review. *Neuroradiology Journal*, *25*(4), 427–451. https://doi.org/10.1177/197140091202500406
15. Guedes, M. dos S., Queiroz, I. C., & de Castro, C. C. (2020). Classification and clinical significance of intracranial calcifications: A pictorial essay. *Radiologia Brasileira*, *53*(4), 273–278. https://doi.org/10.1590/0100-3984.2019.0094
16. Hénaut, L., Mentaverri, R., Liabeuf, S., Bargnoux, A. S., Delanaye, P., Cavalier, É., Cristol, J. P., Massy, Z., & Kamel, S. (2015). Pathophysiological mechanisms of vascular calcification. *Annales de Biologie Clinique*, *73*(3), 271–287. https://doi.org/10.1684/abc.2015.1044
17. Jain, S., Choudhary, K., Nagi, R., Shukla, S., Kaur, N., & Grover, D. (2019). New evolution of cone-beam computed tomography in dentistry: Combining digital echnologies. *Imaging Science in Dentistry*, *49*(3), 179–190. https://doi.org/10.5624/isd.2019.49.3.179
18. Jay Mohan; Karan Bhatti; Adam Tawney; Roman Zeltser. (2016). Coronary Artery Calcification. *Global Heart*, *11*(3), 287–293. https://doi.org/10.1016/j.gheart.2016.08.001
19. Jono, S., Shioi, A., Ikari, Y., & Nishizawa, Y.

(2006). Vascular calcification in chronic kidney disease. *Journal of Bone and Mineral Metabolism*, *24*(2), 176–181. https://doi.org/10.1007/s00774-005-0668-6

20. Kim, H. S., Kim, D. M., Ju, C. Il, & Kim, S. W. (2013). Intracranial calcification caused by a brain abscess: A rare cause of intracranial calcification. *Journal of Korean Neurosurgical Society*, *54*(2), 148–150. https://doi.org/10.3340/jkns.2013.54.2.148
21. Kumar, M., Shanavas, M., Sidappa, A., & Kiran, M. (2015). Cone beam computed tomography - know its secrets. *Journal of International Oral Health : JIOH*, *7*(2), 64–68. http://www.ncbi.nlm.nih.gov/pubmed/25859112%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4377156
22. Li, X., Du, H., Li, J., & Chen, X. (2023). Intracranial artery calcification as an independent predictor of ischemic stroke: a systematic review and a meta-analysis. *BMC Neurology*, *23*(1), 21–28. https://doi.org/10.1186/s12883-023-03069-x
23. Mutalik, S., & Tadinada, A. (2017). Prevalence of pineal gland calcification as an incidental finding in patients referred for implant dental therapy. *Imaging Science in Dentistry*, *47*(3), 175–180. https://doi.org/10.5624/isd.2017.47.3.175
24. Nguyen, M., & Enciso, R. (2012). *Intracranial physiological calcifications evaluated with cone beam CT*. *41*, 675–678. https://doi.org/10.1259/dmfr/33077422
25. Osborn, A. G., & Preece, M. T. (2006). Intracranial cysts: Radiologic-pathologic correlation and imaging approach. *Radiology*, *239*(3), 650–664. https://doi.org/10.1148/radiol.2393050823
26. Price, J. B., Thaw, K. L., Tyndall, D. A., Ludlow, J. B., & Padilla, R. J. (2012). Incidental findings from cone beam computed tomography of the maxillofacial region: A descriptive retrospective study. *Clinical Oral Implants Research*, *23*(11), 1261–1268. https://doi.org/10.1111/j.1600-0501.2011.02299.x
27. Rath, T. J., Hughes, M., Arabi, M., & Shah, G. V. (2012). Imaging of Cerebritis, Encephalitis, and Brain Abscess. *Neuroimaging Clinics of North America*, *22*(4), 585–607. https://doi.org/10.1016/j.nic.2012.04.002
28. Saade, C., Najem, E., Asmar, K., Salman, R., Achkar, B. El, & Naffaa, L. (2020). *Intracranial calcifications on CT : an updated review*. *13*(3), 1–18. https://doi.org/10.3941/jrcr.v13i8.3633
29. Scarfe, W., Farman, A., & Sukovic, P. (2006). Clinical Applications of Cone-Beam Computed in Dental Pratice. *J Can Dent Assoc*, *72*(1), 75–80.
30. Spagnuolo, G. (2022). Cone-Beam Computed Tomography and the Related Scientific Evidence. *Applied Sciences (Switzerland)*, *12*(14), 12–14. https://doi.org/10.3390/app12147140
31. Umeoka, S., Koyama, T., Miki, Y., Akai, M., Tsutsui, K., & Togashi, K. (2008). Pictorial review of tuberous sclerosis in various organs. *Radiographics*, *28*(7). https://doi.org/10.1148/rg.e32
32. van der Toorn, J. E., Engelkes, S. R., Ikram, M. K., Ikram, M. A., Vernooij, M. W., Kavousi, M., & Bos, D. (2019). Vertebrobasilar artery calcification: Prevalence and risk factors in the general population. *Atherosclerosis*, *286*(April), 46–52. https://doi.org/10.1016/j.atherosclerosis.2019.05.001
33. Wu, X. H., Chen, X. Y., Wang, L. J., & Wong, K. S. (2016). Intracranial artery calcification and its clinical significance. *Journal of Clinical Neurology (Korea)*, *12*(3), 253–261. https://doi.org/10.3988/jcn.2016.12.3.253
34. Yang, W. J., Wasserman, B. A., Zheng, L., Huang, Z. Q., Li, J., Abrigo, J., Wong, S. S. man, Ying, M. T. cheung, Chu, W. C. W., Wong, L. K. sing, Leung, T. W. H., & Chen, X. Y. (2021). Understanding the Clinical Implications of Intracranial Arterial Calcification Using Brain CT and Vessel Wall Imaging. *Frontiers in Neurology*, *12*(July), 1–9. https://doi.org/10.3389/fneur.2021.619233