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Utility of CT scans in the management of craniosynostosis: a survey of craniofacial units in Australia and New Zealand

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Abstract

Introduction: The aim of this study is to understand current practices in the use of computed tomography (CT) scans in the routine assessment and management of infants and children with craniosynostosis among surgeons in Australia and New Zealand. No consensus exists in the literature about the utility of CT scans in this patient population.

Methods: A survey was distributed to craniofacial units across Australia and New Zealand, targeting nine paediatric craniofacial programs and requesting information about the routine use of CT scans in the management of craniosynostosis.

Results: The response rate was 49 per cent with the majority (75%) of responding surgeons having more than 10 years of experience in craniofacial surgery. Input from all units was obtained. Ninety-five per cent of surgeons order preoperative CT scans for single-suture craniosynostosis, with the stated indication being confirmation of diagnosis (85%), characterisation of cranial morphology (70%), detection of raised intracranial pressure (65%) and screening for associated anomalies (85%). The majority (85%) of surgeons used standard radiologic protocols. Only 10 per cent of respondents do routine postoperative CT scans. In multiple-suture and syndromic craniosynostosis, the use of routine postoperative CT scans was greater. Access issues were a factor in many units due to rural locations.

Conclusion: Routine CT scans are employed in the diagnosis and management of infants and children with craniosynostosis in craniofacial units in Australia and New Zealand. Variability in practice suggests an opportunity for standardisation of protocols. Accessibility to CT scans and ethical issues regarding radiation exposure are an issue in many units.

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Introduction

Craniosynostosis occurs in 1 in 2000 infants due to premature fusion of one or more cranial sutures, leading to an abnormal skull shape and potentially affecting brain growth and development. This condition can present as either non-syndromic or syndromic, and may involve a single suture or multiple sutures.¹ Computed tomography (CT) scans have traditionally been the gold standard for diagnosing craniosynostosis due to their ability to provide detailed images of the cranial sutures and surrounding structures.² However, the use of CT scans, especially in children, raises concerns about radiation exposure and its potential long-term risks. Recent literature, including studies by Alnaif and colleagues and Fahradyan and colleagues, has questioned the necessity of routine preoperative CT scans, suggesting that alternative imaging modalities and thorough clinical examinations might be sufficient in certain cases.^{3,4} Despite these concerns, there is no consensus within Australia and New Zealand regarding the routine use of CT scans in the management of craniosynostosis.

The lack of standardised guidelines for the use of CT scans in craniosynostosis can lead to inconsistent patient care and potentially unnecessary exposure to radiation. The aim of this study is to understand current practices in the use of CT scans for the routine assessment and management of infants and children with craniosynostosis among surgeons in Australia and New Zealand.

Methods

A survey (see **Supplementary material 1**) was distributed to craniofacial surgeons working in nine units across Australia and New Zealand. The survey was sent electronically via Google Forms and was open for responses for four weeks, between 8 November 2024 and 6 December 2024. Two email reminders were sent before the deadline.

Responses were anonymised and all collected data was deidentified. Responses were categorised based on the participants' country and state of practice, professional experience and specialty. Respondents who are not currently consultants or do not currently practice in Australia or New Zealand were excluded from the analysis.

Results

Participant demographics

A total of 26 out of 41 surgeons responded to the survey, however only 20 responses met our inclusion

criteria (consultants, and currently practicing in Australia or New Zealand) for a response rate of 49 per cent. Fourteen of the respondents are plastic surgeons and six are neurosurgeons. The vast majority are male (75%). Of the four women who responded, three are neurosurgeons.

The majority (75%) of respondents have over 10 years of experience. Responses were received from each state and territory in Australia (except for the Northern Territory, which does not have a dedicated craniofacial unit) and New Zealand. New South Wales had the most responses (seven), followed by Victoria and Southern Australia (four responses each).

Initial workup

The majority of respondents (95%) recommend obtaining CT scans for suspected single-suture craniosynostosis, while all respondents routinely obtain CT scans for suspected multiple and syndromic craniosynostosis. Seventeen respondents (85%) confirmed that their institution uses a standardised protocol for CT scans, however only two respondents said that their decision to obtain a CT scan is guided by specific protocol guidelines. On the other hand, 85 per cent of respondents make a decision on the necessity of a CT scan based on clinical presentation alone (**Table 1**). When asked what specific information they seek from CT scans in cases of suspected craniosynostosis, most respondents primarily use CT scans for diagnostic purposes (85%), followed by assessment of the extent of suture fusion (75%) (**Table 1**). Other applications identified by respondents for CT use include assessing bone thickness and anatomy, looking at the internal bone anatomy, detection of emissary veins, assessment of skull base anatomy and using the CT as an educational tool for parents.

Impact on treatment and outcomes

The majority of respondents indicated that a preoperative CT is routinely obtained (95%), is important for planning surgery (90%) and improves outcomes (70%). Other applications of CT use in patient management included facilitating earlier surgery (45%), monitoring progression and relapse (40%), providing a clearer prognosis (75%) and having a research benefit (50%) (**Table 1**).

CT scans were deemed particularly useful in detecting unanticipated multiple-suture synostosis, pansynostosis and signs of raised intracranial pressure (ICP), as well as identifying structural anomalies of the brain and the presence of emissary

Table 1. Respondent use of CT scans in craniosynostosis

	Number of 'Yes' responses (n)	Percentage of 'Yes' responses (%)
What specific information do you primarily seek from CT scans in cases of suspected craniosynostosis?		
Routinely obtain CT	19	95
Establishing/confirmation of diagnosis	17	85
Assess extent of suture fusion	15	75
Evaluation of cranial shape abnormalities	14	70
Detection of elevated intracranial pressure (ICP)	13	65
Detection of associated anomalies	17	85
How does a CT scan influence your treatment planning in craniosynostosis cases?		
Directly affects surgical planning	18	90
Helps monitor disease progression	8	40
Confirms clinical suspicion	16	80
No significant impact	1	5
How do you determine the necessity of performing a CT scan in cases of suspected craniosynostosis?		
Based on clinical presentation alone	16	80
Based on severity of symptoms	0	0
Based on initial imaging (X-ray, ultrasound)	1	5
Based on specific guidelines or protocols	2	10
From your experience, how does the use of CT scans affect patient outcomes in craniosynostosis cases?		
Improves surgical outcomes	13	65
Facilitates early intervention	9	45
Provides clearer prognosis	15	75
Useful for research purposes	10	50
Helps avoid complications	1	5
Rules out associated anomalies	1	5
What symptoms/signs in a patient with a diagnosed craniosynostosis would make you want to order a CT scan for a craniosynostosis patient?		
Headaches	17	85
Bone defects	17	85
Abnormal bony prominences	10	50
Head shape (eg, relapse)	18	90
Tense fontanelle	13	65

veins. Respondents also noted that CT imaging can inform surgical planning, specifically guiding soft tissue flap elevation and determining the extent of skeletal surgery. Additionally, CT scans are considered valuable in cases where venous outflow abnormalities or atypical head shapes might affect surgical decisions. The use of contrast-enhanced CT was noted for assessing venous drainage concerns, particularly in syndromic cases. Some respondents mentioned that CT scans aid in both syndromic and non-syndromic craniosynostosis surgeries by providing crucial anatomical details: one respondent specifically mentioned their role in procedures like fronto-orbital advancement and remodelling, where CT helps locate the sphenoid wing and guide bony cuts. CT scans were also a useful tool for discussions with parents, helping to explain the condition and treatment plan.

Postoperative follow-up and monitoring of progression and relapse

There is great variability in the use of postoperative CT scans. Immediate postoperative CT scans are rarely performed in cases of single-suture craniosynostosis, with only 10 per cent of respondents routinely obtaining them. However, their use increases in more complex cases, with 35–40 per cent of respondents routinely performing postoperative CT scans for multiple-suture and syndromic craniosynostosis.

Late postoperative CT scans, defined as imaging performed more than one year after surgery, have limited use in single-suture craniosynostosis, with only 25 per cent of respondents routinely obtaining them. The frequency increases slightly in cases of multiple-suture craniosynostosis and syndromic craniosynostosis at 30 per cent.

Three respondents clarified that they routinely perform CT scans six weeks postoperatively, while one respondent explained that their department only routinely obtains one-year postoperative CT scans for patients who underwent strip craniectomies, not for other procedures.

In long-term follow-up, headaches and head shape abnormalities are the most commonly cited signs and symptoms that would prompt ordering a CT scan. Other indications for a CT included bone defects, the presence of a tense fontanelle and abnormal bony prominences (**Table 1**).

Our results show that the majority of respondents (55%) use CT scans as the initial imaging modality in patients with suspected increased ICP. However, 35 per cent of respondents indicated that they do

not rely on CT scans as the first diagnostic tool for suspected increased ICP. A small number of respondents indicated a more specific approach, with one using CT in conjunction with MRI and fundoscopy, and another considering the patient's age and clinical concerns when deciding between CT and MRI.

Imaging modalities

The majority (85%) of respondents reported using non-contrast CT as their preferred imaging modality. One indicated that the choice of CT type depends on the clinical situation, while another specified using non-contrast CT for single-suture craniosynostosis and CT venography for syndromic cases. Additionally, one respondent highlighted the use of fine-cut bony windows. When asked about alternative imaging modalities in suspected craniosynostosis, the survey results indicate the majority of respondents (75%) do not use ultrasound. MRI is used by six respondents, while traditional X-ray imaging is still used by seven respondents (**Table 2**). Three-dimensional (3D) photography appears to be a more frequently used adjunct to diagnostic tests, with 10 respondents incorporating it into their assessment. Finally, magnetic resonance venography (MRV) or magnetic resonance angiography (MRA) is used by six respondents.

Table 2. Respondent use of other imaging modalities in craniosynostosis evaluation

Modality	Yes: n (%)	No: n (%)	No answer
Ultrasound	3 (15%)	17 (75%)	0
Plain X-ray	11 (55%)	7 (35%)	2 (10%)
3D camera	10 (50%)	8 (40%)	2 (10%)
MRI	6 (30%)	11 (55%)	3 (15%)
MRA/MRV	6 (30%)	12 (60%)	2 (10%)

The Yes column represents respondents who use the modality, while the No column represents those who do not

Accessibility

Forty per cent of respondents noted that coordinating travel for rural families to tertiary centres can be complex and may lead to delays in obtaining scans. The primary difficulties identified were related to patients requiring sedation or general anaesthesia for imaging. Additionally, concerns were raised about the variable quality of imaging in remote centres, which may impact diagnostic accuracy. One

respondent highlighted the extreme wait times for MRI, further complicating access to imaging in certain cases. Fifty-five per cent of respondents indicated that they do not encounter accessibility issues impacting the ability to obtain CT scans.

Ethical considerations and radiation exposure

Among those who reported ethical concerns, the primary issue cited was the potential long-term risk of radiation exposure, particularly in young children, as early radiation exposure has been linked to an increased lifetime cancer risk.⁵ Several noted that while low-dose CT protocols have helped mitigate these risks, they may come at the cost of reduced diagnostic accuracy. Others expressed a preference for minimising routine postoperative CT scans, particularly in cases of single-suture craniosynostosis, and instead using non-radiation-based modalities such as 3D photography for postoperative follow-up in uncomplicated cases.

Discussion

This is the first binational imaging survey of paediatric craniofacial units with comprehensive input from all centres in Australia and New Zealand, demonstrating that the majority of respondents support the routine use of CT scans in the management of infants with single, multiple and syndromic craniosynostosis. This study has highlighted variability and the absence of standard protocols across units and raised issues regarding accessibility and ethical concerns about radiation exposure ensuring 'as low as reasonably achievable' (ALARA) standards.⁶

There have been several previous studies highlighting the routine use of CT scans in the management of infants with craniosynostosis. Makar and colleagues surveyed all 614 active members of the American Society of Maxillofacial Surgeons and American Society of Craniofacial Surgeons to ascertain practice patterns and had a 13.8 per cent response rate to their questionnaire.⁷ Their findings demonstrated that the majority of craniofacial surgeons use preoperative CT scans while 9.3 per cent of surgeons do not. Ziariaris and Marucci performed a survey of all eight craniofacial centres in Australia and New Zealand in 2019, and found that six out of eight centres routinely perform preoperative CT scans on single-suture craniosynostosis patients, while all eight centres perform routine preoperative CT scans on multiple-suture craniosynostosis.⁸ This

is in line with our findings, where all surgeons obtain CT scans in cases of suspected multiple-suture craniosynostosis.

Alnaif and colleagues performed a systematic literature search to assess articles reporting the use of preoperative CT scans in non-syndromic craniosynostosis.³ The results of their meta-analysis revealed 11 articles that met their criteria for inclusion, with a total of 728 patients, and supported the use of CT scans in the absence of alternative imaging modalities. Furthermore, the authors highlighted the fact that in studies where no alternative imaging was considered, CT altered the diagnosis or led to additional investigations in 12 out of 248 cases (4.8%). In this group, 7 out of 248 (2.8%) patients received the wrong diagnosis based on physical examination. CT scans demonstrated incidental intracranial pathologies in a small (1.79%) but important group of patients.³

The importance of using CT scans to establish or confirm the diagnosis of craniosynostosis was noted by 85 per cent of respondents in our study. While most experienced craniofacial providers can establish the diagnosis of single-suture craniosynostosis, challenges with lambdoid and occasionally sagittal synostosis have been highlighted.⁹ In the literature, concordance of CT scan findings with clinical examination has been reported to be between 93.3 per cent and 100 per cent.³ Missed or incomplete diagnoses based on clinical assessment were detected in 8 out of 379 (2.1%) patients, which may have led to unnecessary or incomplete surgery.³

Routine immediate postoperative CT scan utilisation is not supported by the respondents of this study. Ahammout and colleagues, in a two-centre assessment of postoperative CT reports in 506 patients undergoing cranial vault reconstruction, found that abnormal radiologic findings are present in 6.5 per cent of cases but resulted in medical/surgical intervention in only 3 out of 506 (0.55%) patients.¹⁰ They emphasised that the decision to postoperatively scan a patient should be a balanced one, taking into account the low chance of finding an anomaly and the risks of the CT.

The implicit concern about radiation exposure in infants continues to influence the routine application of CT scans and was raised in our study. The introduction of low-dose, bone-only protocols in CT imaging has resulted in significant reductions in radiation exposure and demonstrated not to compromise imaging detail.¹¹ However, the linear-no-threshold hypothesis indicates that exposure

to ionising radiation at any level has the potential to increase the likelihood of the development of malignancy later in life, even for a single CT study.^{12,13} The ALARA protocols emphasise that there is no safe dose of radiation, especially for infants and young children.⁶ A recent study in a multinational cohort of 948,174 individuals who underwent CT examinations before age 22 years suggested that for every 10,000 children examined today (mean dose 8 mGy), one to two are expected to develop a haematological malignancy attributable to radiation exposure in the subsequent 12 years.⁵ They emphasised the increasing body of evidence that even low radiation doses result in increased cancer risk in young patients.

The use of black bone MRI has been introduced as an alternative to CT but requires sedation/anaesthesia for infants to successfully be imaged. For the past two decades, there have been concerns surrounding cardiopulmonary risks in young infants and long-term neurocognitive effects on the developing brain from sedative/anaesthetic drug exposure.^{14,15} Callahan and colleagues raised the issue of using MRI as an alternative to CT in order to mitigate radiation risk.¹³ They demonstrated that the risks of ionising radiation and sedation/anaesthesia were small but generate anxiety and concern amongst paediatricians and parents, and concluded that comparing the carcinogenesis risks from CT ionising radiation against the anaesthesia risks for MRI is an extremely complex and challenging topic that does not lend itself to a straightforward conclusion. The respondents in this study favoured the use of MRI in complex syndromic and multiple-suture craniosynostosis cases, but not routinely for single-suture craniosynostosis.

Government reports demonstrate that 28 per cent of Australians live in rural and remote areas and face unique health care challenges due to their geographical location.¹⁶ Data shows that people living in rural and remote areas have higher rates of hospitalisation, death and injury, and also have poorer access to, and use of, primary health care services than people living in metropolitan areas.^{16,17} This was highlighted by several respondents in this study stating that access to CT and quality of imaging affected an important proportion of their patients.

Finally, while most centres use some radiologic CT protocols, there appears to be no standardised guidelines on CT use in craniosynostosis. Given the cohesion and small number of units across Australia and New Zealand, opportunities to develop consensus and standard protocols would enhance care and research opportunities. It is hoped that this study can provide some impetus for collaboration on this topic.

Limitations

While regional differences in CT scan usage and diagnostic practices were noted, this study does not investigate the reasons behind these variations. The study may also be subject to selection bias, as the questionnaire was distributed electronically through professional networks, which may not have captured a fully representative sample of all surgeons managing craniosynostosis in Australia and New Zealand. Finally, data on surgical volumes was not collected and correlated in this study.

Conclusion

Routine CT scans are employed in the diagnosis and management of children with craniosynostosis in all craniofacial units in Australia and New Zealand. Variability in practice suggests an opportunity for standardisation of protocols. Access to CT scans due to rural locations and ethical issues regarding radiation exposure are an issue in many units.

Participant consent

Participants have given informed consent to the publication of images and/or data.

Conflict of interest

The authors have no conflicts of interest to disclose.

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