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COMMENTARY

Utilization of volumetric magnetic resonance imaging for baseline and surveillance imaging in Neuro-oncology

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ABSTRACT

The acquisition of volumetric post-contrast MRI has clear advantages in the interpretation of neuro-oncology studies but has yet to find its way into routine clinical practice beyond planning scans for surgery and radiotherapy. This commentary briefly highlights the benefits of these techniques whilst dispelling some of the perceived disadvantages.

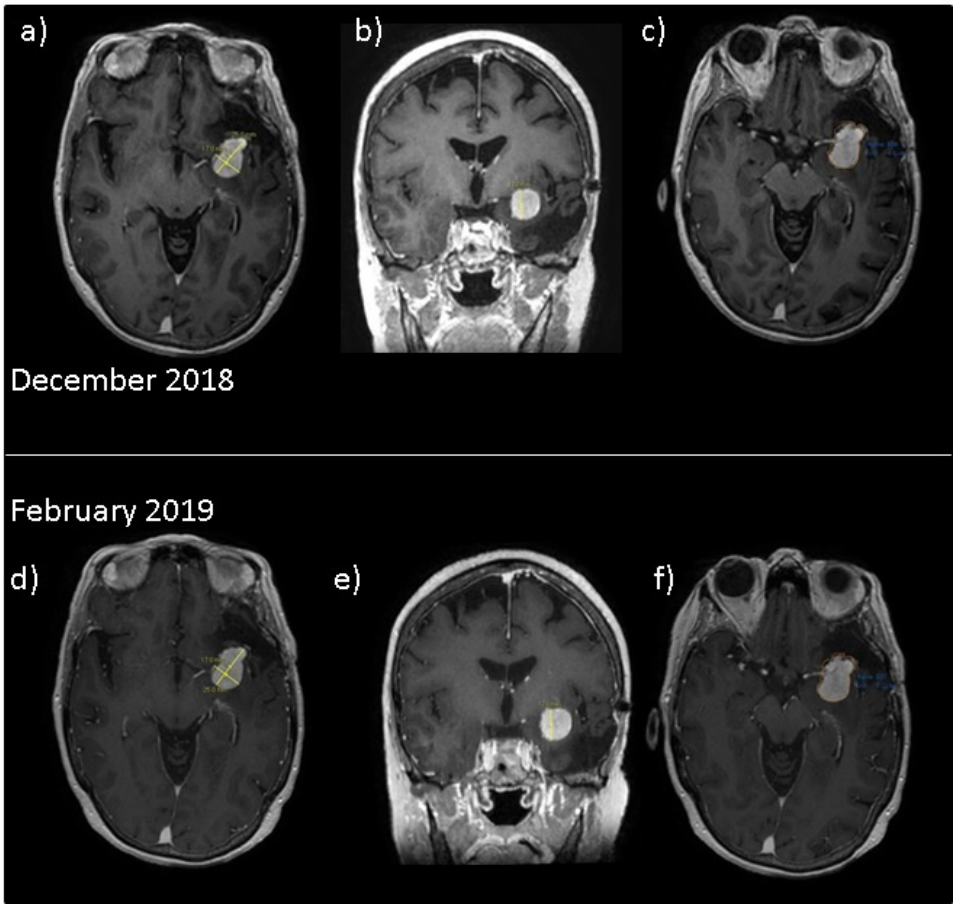
INTRODUCTION

Volumetric MRI sequences have improved greatly over the years but continue to be reserved for surgical and radiotherapy planning purposes and clinical trials, rarely forming part of routine contrast-enhanced studies of the brain.[1] The authors would like to highlight the value of these sequences in routine neuro-oncological clinical practice in both baseline (diagnostic) and surveillance imaging, especially with regard to brain metastases and meningioma. The NICE guidelines for brain tumours in adults were published in July 2018[2] and recommend both pre- and post-contrast volumetric imaging as part of the standard structural imaging protocol for glioma, meningioma and brain metastases. A more detailed protocol on specific sequences and technicalities of sequence acquisition has been published by the British Society for Neuroradiologists and this also recommends volumetric imaging sequences for glioma.[3] Although these recommendations exist, routine volumetric image acquisition in brain imaging has yet to find widespread adoption into clinical practice.

ADVANTAGES

There are several advantages of performing volumetric imaging at baseline. First, it may negate the need for an additional MRI study to obtain the volumetric sequences necessary for either surgical or radiotherapy planning thereby saving the patient from a repeated, unnecessary second dose of gadolinium contrast medium,[4] and by reducing duplicate imaging which would be a cost saving for the NHS. Second, the inclusion of volumetric sequences in surveillance imaging protocols would allow the application of co-registration techniques, which have been shown to increase sensitivity in identifying pathological changes.[5] Co-registration techniques are readily available on most picture archiving and communication system systems. Furthermore, it "future proofs" any scans acquired, so that retrospective analysis can be performed

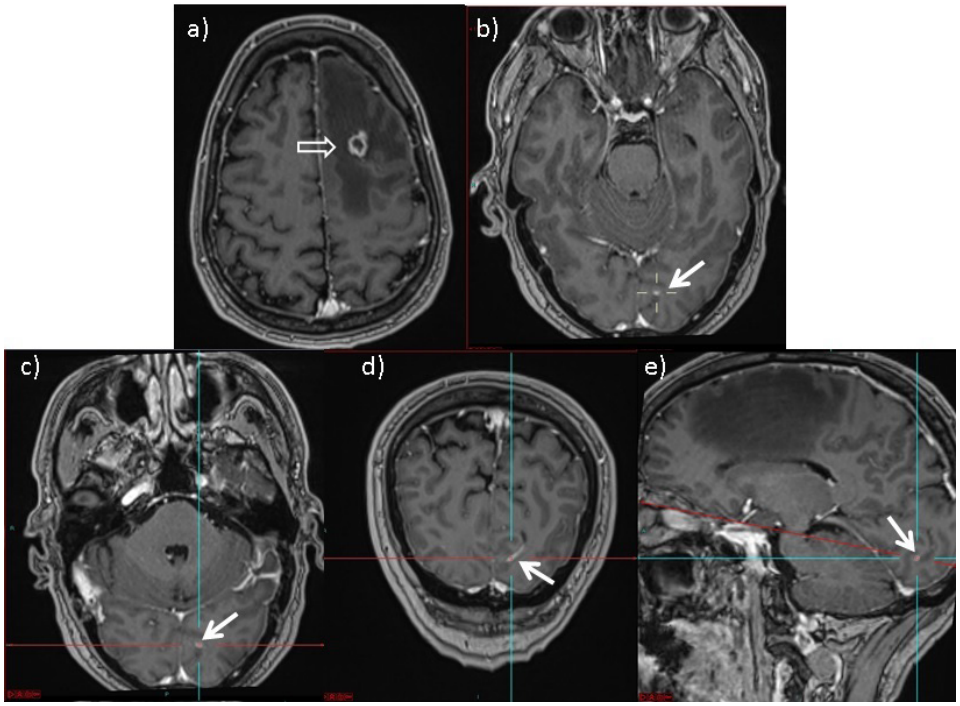
Figure 1. Post-contrast T_1 weighted imaging of a patient with a recurrent left sphenoid meningioma. (a) and (b) Axial and coronal reformats from a volumetric post-contrast T_1 acquisition demonstrating conventional maximum trans-axial and coronal two-dimensional measurements from December 2018 with (c) demonstrating the semi-automated volumetric measure of the meningioma recurrence. (d–f) show corresponding images to (a–c) acquired 2 months later in February 2019 demonstrating no measurable change on conventional two-dimensional measurements but an approximately 8% increase in volume when quantitative volumes are obtained increasing from 4.8 to 5.2 cm^2.



at a later stage including quantitative volumetric assessment[6,7] or "radiomic" approaches utilising textural analysis.[8] Volumetric measures also detect tumour growth more accurately (Figure 1) and are increasingly being utilized in drug development trials.[9] Furthermore, the use of radiosurgery for brain metastases has increased, in part due to the increased survival seen with new cancer therapies including immunotherapy. Volumetric imaging permits earlier detection of metastases, making the best use of modern radiosurgery platforms capable of treating multiple targets prior to clinical deterioration.[10]

There is evidence suggesting quantitative volumetric measurements can provide additional prognostic information with regard to glioma. In low-grade glioma, changes in volume growth rate on T2 and FLAIR sequences can predict early malignant dedifferentiation[11] and have shown better prediction of malignant transformation compared to baseline volumetric measurement, relative cerebral blood volume (perfusion imaging) and measurements of apparent diffusion co-efficient (diffusion imaging).[12] Following surgical treatment for glioblastoma, a recent study has suggested that it is the actual volume of the tumour residuum rather than extent of resection, which has a greater effect on patient prognosis.[13] Interestingly, a comparison of two-dimensional RANO (response assessment in neuro-oncology) criteria and volumetric measurements in the first 12 weeks of bevacizumab treatment for glioblastoma multiforme (GBM) did not demonstrate an advantage to performing a quantitative volumetric measurement over the more simple two-dimensional RANO measures,[14] although not acknowledged by the authors, the acquisition of a volumetric sequence would ensure more reliable comparison with preceding studies via co-registration techniques to improve the accuracy of the two-dimensional measures. The routine incorporation of volumetric sequences into neuro-oncology imaging protocols would allow these measurements to be more easily made, if so desired. Manual delineation of tumour volumes is time consuming and can be prone to inter- and intraobserver error but software is now readily available which allows automated volume measurement and has been shown to be more reliable than manual delineation.[15]

Figure 2. (a) Axial T_1 MPRAGE showing a left frontal cerebral metastasis from renal cell carcinoma (open white arrow). (b) The solid white arrow identifies an indeterminate focus of enhancement in the left occipital lobe, there is uncertainty on this axial imaging whether this reflects a separate small metastasis. (c–e) Standard axial, coronal and sagittal reformats of 3D imaging respectively shows enhancement (solid white arrow) is linear on the coronal reformat and, in fact, represents a vessel rather than a second metastatic deposit. 3D, three-dimensional.



Practically, volumetric acquisitions typically take 7–8 min to perform per sequence and can be reformatted into any plane thus negating the need to acquire two different non-contiguous slice sequences (typically taking 4–5 min per acquisition). This is a more time-efficient method and the ability to reformat in any plane removes the ambiguity over whether contrast enhancement is genuine or a vascular entity (Figure 2). Consensus papers on recommendations for standardized protocols for clinical trials for glioma[1] and neurofibromatosis[16] provide excellent guidance on which post-contrast T_1 protocols to use for volumetric imaging and these would be applicable to metastases and meningioma as well. The authors of these papers acknowledge that alternative and potentially improved volumetric sequences compared to the recommendations are available, but at the time of publication, these sequences were not as widely available as they are today.

PERCEIVED DISADVANTAGES

Some radiologists and reporting radiographers may have concerns that the production of more imaging slices will both increase the error rate and take longer to review. There is no published evidence to support this. In fact, an early study of volumetric imaging demonstrated an increase in lesion conspicuity.[17] Whilst we acknowledge that radiological review and interpretation of volumetric three-dimensional imaging may be more time consuming, this is unlikely to equate to a directly correlated increment in time in relation to the number of image slices, since volumetric image interpretation is processed by the radiologist in a different manner to two-dimensional image interpretation.[18]

Whilst manual segmentation and quantification of tumour volumes is time consuming and can demonstrate considerable inter- and intraobserver variability, validated software is readily available which provides automated and semi-automated methods of tumour volumetric assessment that is reliable and robust.[15]

CONCLUSION

Volumetric imaging can increase efficiency in scan duration, aid diagnostic certainty removing ambiguity over genuine lesions and artefacts, and future proofs studies for more formal volumetric quantification when needed. Although, manual quantification of tumour volume is time consuming and can be error prone, this is not essential in the routine clinical reporting of neuro-oncology scans. If formal volumetric quantification is desired, validated, reliable and robust software is readily available which can perform this rapidly and accurately.

Overall, the benefits of performing volumetric imaging as part of the standard radiological assessment in clinical neuro-oncology seem to outweigh any perceived disadvantages.

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