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# Subtraction magnetic resonance for tumours of the skull base and sinuses: a new imaging technique

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**Abstract**
A new imaging technique is described, in which photographic subtraction as practised in angiography, is combined with Gadolinium enhanced Magnetic Resonance (GdMR) imaging and applied to the investigation of the paranasal sinuses and skull base. The densities on the subtraction image are dependent upon the blood supply of the tissues examined, thus producing a record of their vascularity: in effect a vasculogram. The method has proved to be technically feasible, and is advantageous in certain situations, particularly those in which the anatomy is complex as in the skull base or where normal structures have been distorted by previous surgery. The technique provides a more accurate record of tumour extent than that shown on unsubstracted GdMR scans.

## Introduction

In 1961, Zieses des Plantes introduced photographic subtraction arteriography, a technique which subsequently became a routine procedure in all Radiology departments practising angiography. The method requires an initial control film, in which the photographic densities are reversed, and which is then superimposed on the angiographic studies. Provided the photographic densities are well matched, the resulting print from the pair of films will show only the image of the contrast medium within the vessels. A development of the same technique is Digital Subtraction Angiography, which is non-photographic, and uses a digitalized image with the subtraction process taking place within the computer software.

The method can also be applied to other imaging techniques in which a contrast medium is injected intravenously, such as CT or more recently Magnetic Resonance using the paramagnetic contrast agent Gadolinium Diethylenetriamine Pentaacetic acid (Gd-DTPA). The following is an account of some recent studies of subtraction Gadolinium enhanced Magnetic Resonance (GdMR) for the demonstration of skull base and paranasal sinus tumours.

## Method

The essential requirement is that the post-contrast sequence ($T_1$ weighted spin echo) should reproduce exactly the cross sections of tissue shown on the initial pre-contrast control series. In order to do this the patient's head position must be secured so that there is no movement between the sequences and the patient should not be removed from the scanning tunnel or moved in any way for the administration of Gadolinium. This makes injection into an arm vein impractical. However venipuncture can be made into the dorsum of the foot without disturbing the patient's position. The needle is normally placed in the vein prior to putting the patient in the scanner, and is irrigated with saline while the control series are obtained.

The following sequences are then made: a control sagittal series followed by a control coronal series; after the injection of the contrast medium, the coronal sections are immediately repeated followed by a repeat sagittal series. All sequences are $T_1$ weighted and the shortest acquisition times available are employed.

## Results

Thirteen patients with naso-sinus or skull base tumours have been investigated successfully by this technique. These included eight carcinomata, (Figs. 1 & 2), five of which were adenoid cystic carcinoma; two olfactory neuroblastoma, and single examples of a schwannoma (Fig. 3), a naso-pharyngeal carcinoma (Fig. 4), a meningioma, and a cholesteatoma in the middle ear. Reduction of the acquisition time from 17 minutes for a $T_1$ weighted series on the original scanner to 4 minutes on the present machine makes the technique much more feasible and satisfactory subtraction studies are now obtained on all adult patients other than the claustrophobic, who may not be able to accept the close confines of the scanning tunnel.

## Discussion

It is now generally accepted that magnetic resonance imaging combined with the paramagnetic contrast agent Gadolinium DTPA is the optimum method of showing the full extent of naso-sinus malignancy pre-operatively (Lloyd, 1988; 1989; Lund *et al.*, 1989). The technique is especially important in distinguishing retained secretion

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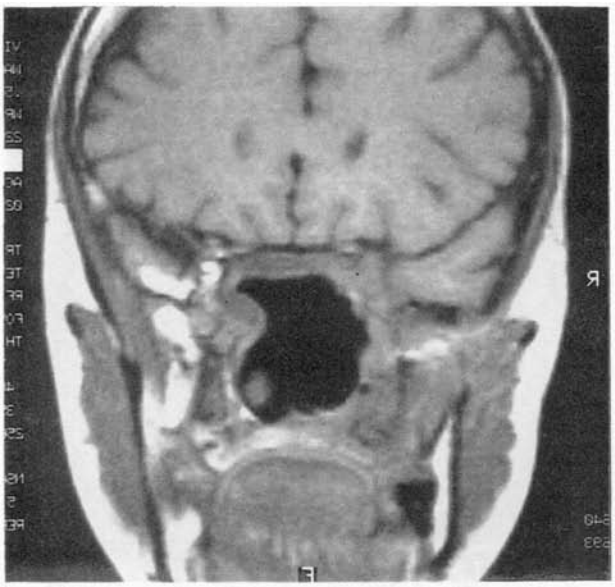

FIG. 1a

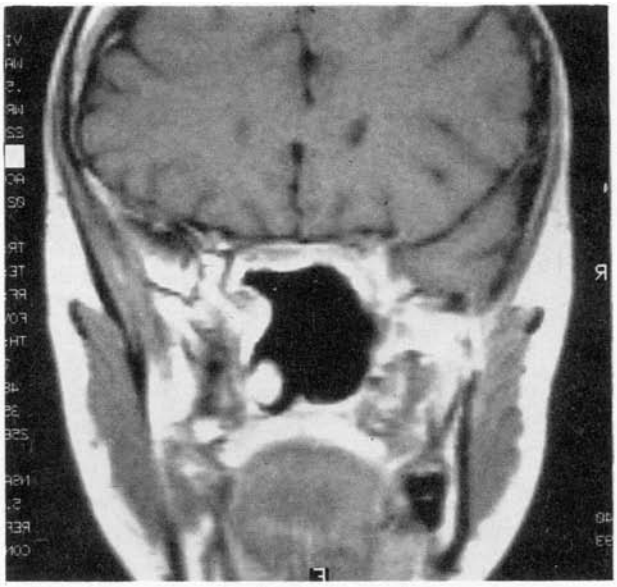

FIG. 1b

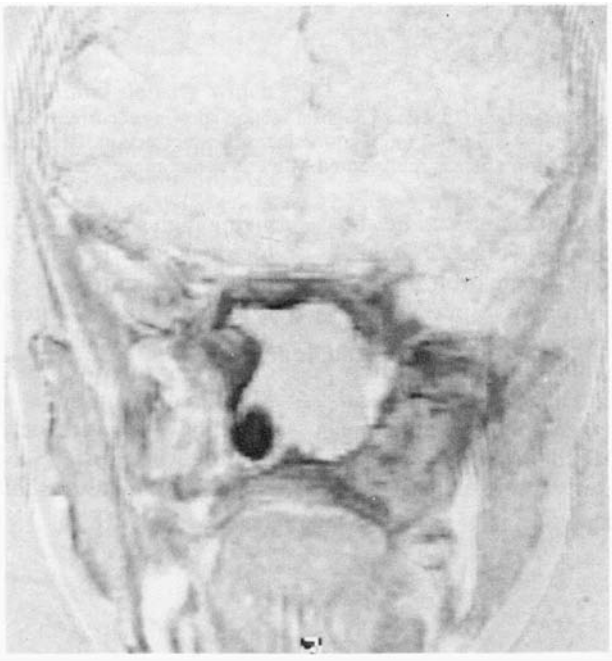

FIG. 1c

FIG. 1

*Recurrent adenoid cystic carcinoma in the nose and sinuses. a) Coronal pre-Gadolinium spin echo sequence. b) The same section after intravenous Gadolinium. c) Subtraction post-Gadolinium scan showing the full extent of tumour infiltration. Multiple biopsies confirmed the presence of recurrent tumour. In order to make the subtraction, the reversed image of a) has been superimposed on b).*

in the sinuses or secondary mucocoele formation from tumour and when the anterior cranial fossa is invaded, separating tumour from cerebral oedema. The effect of gadolinium is to enhance the $T_1$ and $T_2$ relaxation rates of water protons and the increase in relaxation rate is directly proportional to the concentration of the Gadolinium in the tissues. In the initial period following the intravenous injection, delivery of the contrast medium will be dependent on blood supply so that the degree of enhancement will directly reflect tissue vascularity. With subtraction the NMR signal is removed leaving an image in which the density values are dependent only on the vascularity of the tissues concerned, and producing in effect a vasculogram. This image can be advantageous in certain situations, particularly those in which the anatomy is complex as in the skull base, or where normal structures have been distorted by previous surgery.

Since most, but not all, malignant tumours are enhanced following intravenous Gadolinium, these will register on the subtraction scan, the density depending upon their vascularity. Inflammatory changes will also show high density (Fig. 4), and normal structures with high vascularity will show on the subtraction print out. Veins (but not arteries because of their rapid blood flow)

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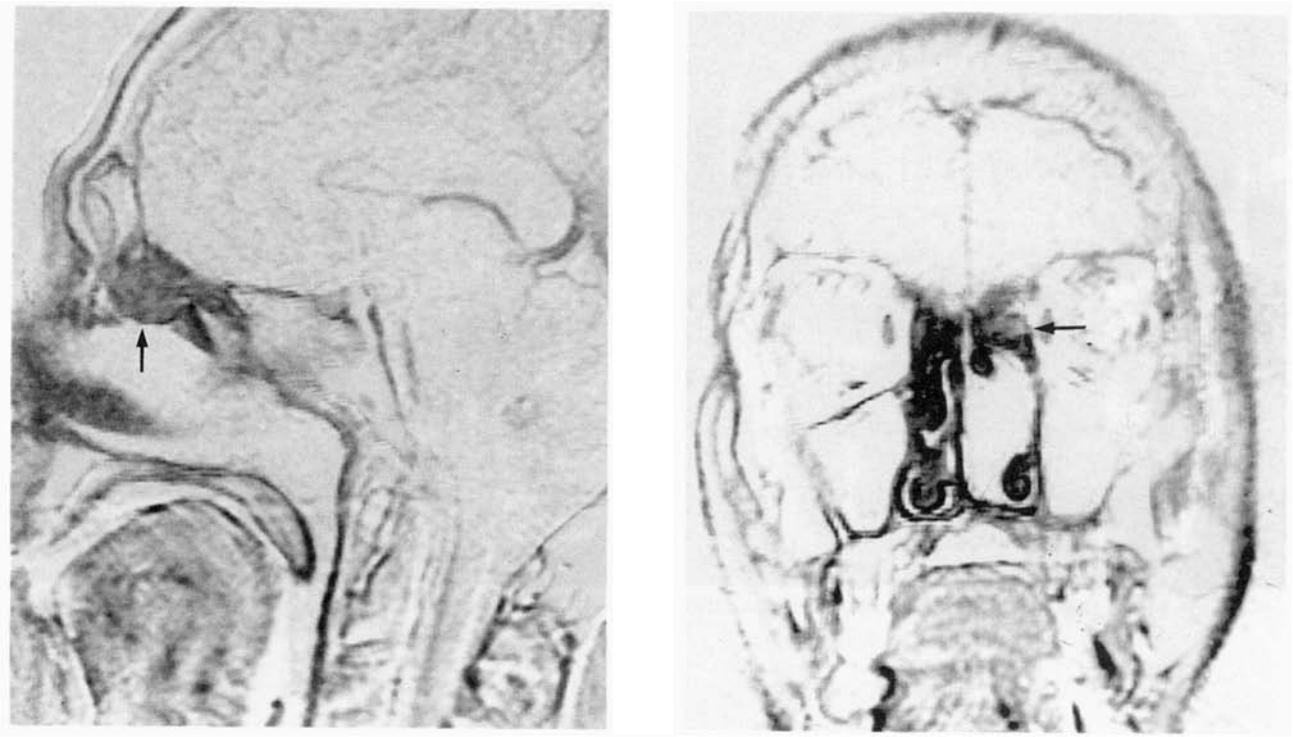

FIG. 2

Recurrent carcinoma of the ethmoids. Subtraction GdMR. a) Sagittal section showing recurrent tumour (arrow). b) Coronal section: the dense image of the highly vascular turbinates and nasal mucosa dominate the subtraction. Recurrent tumour with extension above the cribriform plae is represented by a less dense image. (arrow).

show high density; the nasal and sinus mucosa and the turbinates always enhance strongly (Fig. 2b), while enhancement of muscle is variable. In the orbit the rectus muscles normally enhance strongly, especially the medial rectus and the very vascular lacrimal gland is shown free of obscuring orbital fat, which is completely subtracted off the final image. Fat subtraction is an important advantage of the technique. The effect of Gadolinium is to convert the MR characteristics of vascular tissue to those closely resembling normal fat, giving high signal on $T_1$ weighted sequences, and therefore making it difficult to differentiate fat and tumour on post-gadolinium scans. A partial solution to the problem is to use STIR sequences (Dwyer *et al.*, 1988) which do not record a fat signal. The image produced is however difficult to interpret and frequently of poor resolution. More recent methods use direct fat suppression but these have proved inefficient in some circumstances, notably when surface coils are used. The very low vascularity of fat ensures that with the subtraction method,

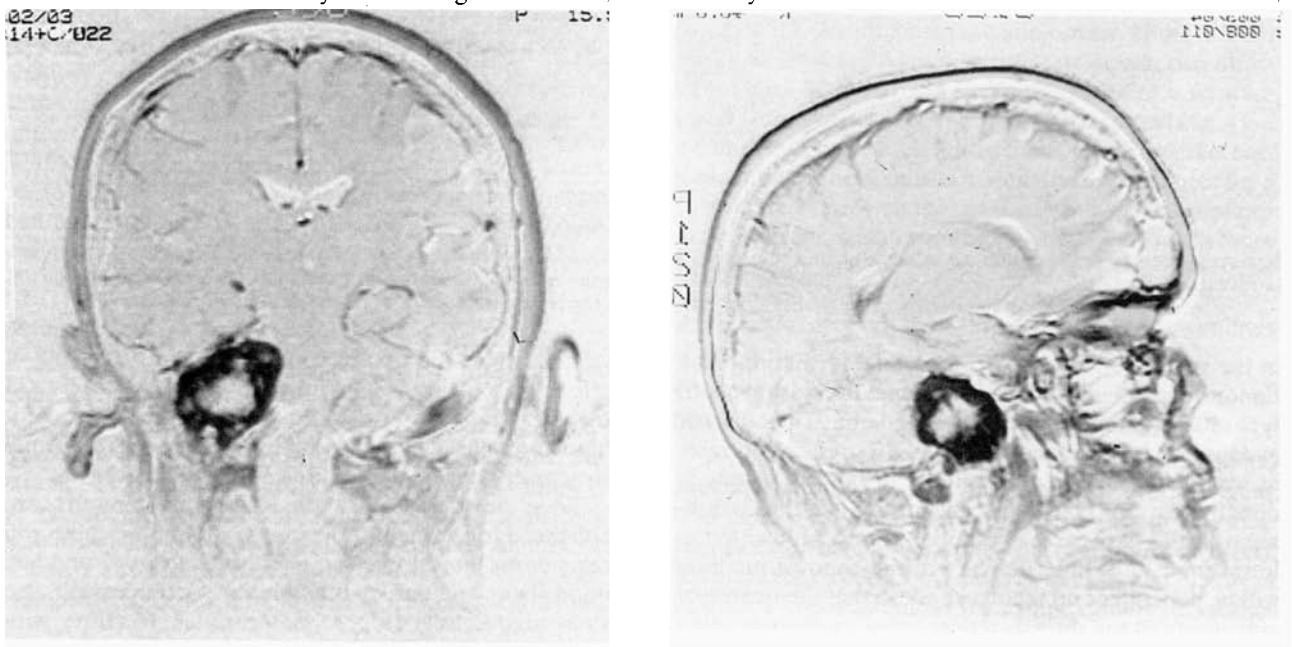

FIG. 3

Jugular fossa schwannoma shown in a) coronal section and b) sagittal section.

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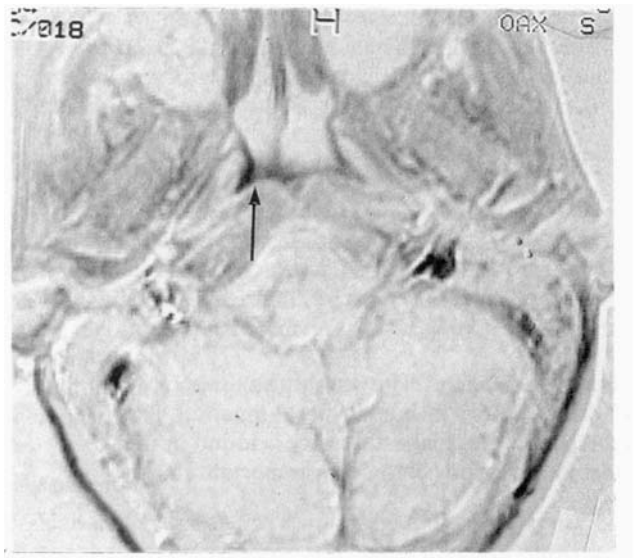


FIG. 4

Proven naso-pharyngeal carcinoma which had been treated by radiotherapy 18 months previously. The axial subtraction GdMR scan demonstrates thickened and hypervascular mucosa at the original tumour site in the fossa of Rosenmuller (arrow). Biopsy showed a chronic inflammatory infiltrate but no tumour.

fat is recorded as an image of minimal density which does not obscure the pathology.

In the nose and sinuses, most tumours produce an enhancement less than that of the turbinates and mucosa so that the tumour outline is often seen as a less dense image against these normal structures (Fig. 2). However with the more vascular tumours, the densities may be closely matched between tumour and normal turbinate and these can be difficult to differentiate on unsubtracted scans. The subtraction films make even minor differences in enhancement more readily appreciated.

## Conclusion

Subtraction GdMR has proved to be a technically feasible and worthwhile procedure in the evaluation of tumour extent in the sinuses and skull base. It provides the best demonstration of the effects of Gadolinium on the NMR signal for both normal and abnormal tissues.

The densities recorded on the subtraction image are dependent on tissue blood supply and provide a more accurate record of tumour extent than that shown on the unsubtracted GdMR scans.

### References

Des Plantes, Z. (1961) Subtraction, Thieme Verlag: Stuttgart.

Dwyer, A. J., Frank, J. A., Reinig, J. W., Hickey, A. M., Doppman, J. L. (1988) Short $T_1$ inversion recovery pulse sequences. Analysis and initial experience in cancer imaging. *Radiology,* **168:** 827–836.

Lloyd, G. A. S. (1988) Diagnostic imaging of the nose and paranasal sinuses. Springer Verlag: London, Heidelburg.

Lloyd, G. A. S. (1989) Magnetic resonance imaging of the nose and paranasal sinuses. *Journal of the Royal Society of Medicine,* **82:** 84–87.

Lund, V. J., Howard, D. J., Lloyd, G. A. S., Cheesman, A. D. (1989) Magnetic resonance imaging of paranasal sinus tumours for craniofacial resection. *Head and Neck,* **11:** 279–283.

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