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Cranial Immobilisation – Is There A Better Way?

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ABSTRACT

Westmead Radiation Oncology Department like many radiation therapy department's has high demands on staffing and equipment resources within the mould room, while continuing to combat a dramatically increasing waiting list. The radiation oncologist at Westmead specialising in cranial irradiation instigated the formation of a research group to explore the most resource effective and accurate way of stabilising cranial patients and to confirm whether the cranial immobilisation protocols already in practice within the department are suitable.

Westmead Radiation Oncology employs four methods of cranial immobilisation; fixed and removable head frames that are used for stereotactic radiosurgery (SRS) and rigid plastic (uvex) and thermoplastic (orfit) casts. The latter two are used for brain lesions and head and neck treatments. With the advent of Intensity Modulated Radiation Therapy – IMRT, and modern day treatment, the field parameters employed are becoming smaller and the shielding more complex as the avoidance of critical organs which may be in the beams pathways is crucial. The necessity for rigid immobilisation and reproducibility on a daily basis is apparent.

INTRODUCTION

Westmead Radiation Oncology Department, like many other radiotherapy departments have excessive high demands on staffing and equipment resources both within the Mould Room and treatment areas whilst combating an escalating waiting list. The radiation oncologist specialising in cranial irradiation at Westmead instigated the formation of a research group to explore the most resourceful, effective and accurate way of stabilising cranial patients and to confirm whether the cranial immobilisation protocols utilised at the present time within the department are effective.

A glance backward to the middle of the last century, immobilisation techniques employed the use of rice bags and the time honoured sticky tape to support the head. Other aids employed, were tattooing the baseline once it was in a vertical position, for total cranial irradiation, and marking the field parameters with gentian violet. Smaller field parameters were again outlined with gentian, the field centre being tattooed. For those of you new to the profession, gentian violet is indelible and spillage caused no end of problems, especially to the hapless student who invariably was given the job of touching up the marks.

Today we have personal masks slotted into custom made castboards for individual couch tops. See figure 1.

Modern day radiotherapy utilises small field parameters with complex shielding to avoid critical organs which may be in the pathway of the beams. The necessity for rigid immobilisation and reproducibility on a daily basis is apparent.

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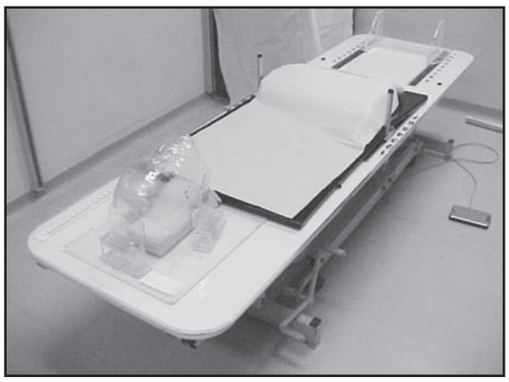

Figure 1: Westmead Hospital Radiation Oncology Castboard System.

Westmead Immobilisation Methods

Westmead employs four methods of Cranial Immobilisation: 1) Fixed and Relocatable head frames for Stereotactic Radiosurgery (SRS), 2) Rigid plastic and 3) Thermoplastic casts, complete the methods employed to render the cranium in a fixed position reproducible on a daily basis, so that radiation can be delivered in a safe and effective manner to the part of the brain the tumour may be situated.

The importance of radiotherapy is to deliver dose to the target volume while minimising risk to surrounding structures. Many cranial immobilisation systems have been developed over the years. The function is to maintain the patient's body in the same reproducible position while restricting mobility during treatment. The immobilisation device must be comfortable, yet simple to implement. In addition, it must not interfere with the treatment delivery. The system should not cause artifacts with the beam for planning purposes and have no beam attenuation for treatment purposes.

Stereotactic Radiosurgery Headframes (SRS)

The Brown-Roberts-Wells (BRW) Fixed head frames for SRS involves a surgical procedure, this involves discomfort for the

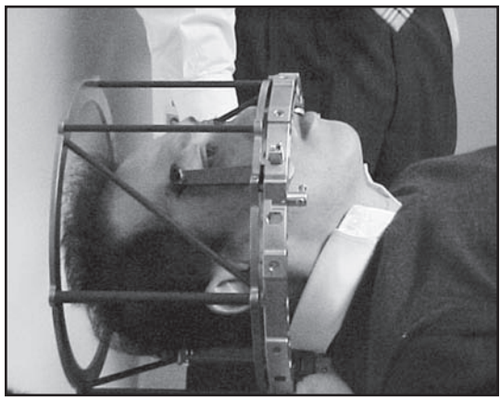

Figure 2: The Brown-Robert-Wells (BRW) Fixed Stereotactic Head Frame.

patient, as the frame is attached to the skull with four screws, in addition, there is the introduced risk of infection.1 This frame is typically used for single fractions. See Figure 2.

The Gill-Thomas-Cosman (GTC) Relocatable frames for stereotactic radiation comprises of a standard head ring to which an individualised dental impression of the upper teeth and a moulded occipital head support are attached. They are more comfortable for the patient than the fixed frame, with the added bonus being quick release, in the event of an emergency, such as a seizure or claustrophobia. They can be used for multi-fractionated treatments.Patient's requiring relocatable head frames should have good dentition for the use of the mouth blocks.[2] See Figure 3.

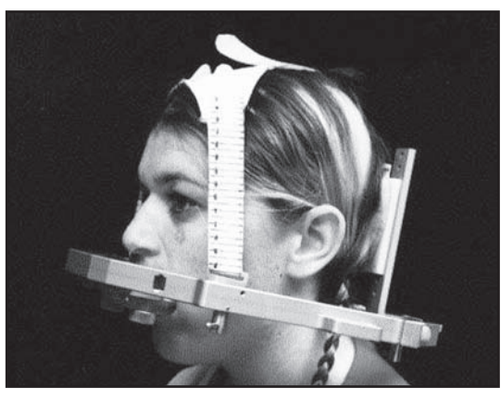

Figure 3: The Gill-Thomas-Cosman (GTC) Relocatable Stereotactic Frame.

Rigid Plastic Casts

Rigid plastic casts (commonly referred to as Uvex) need to be made from a mould, this involves two separate visits to the department. One for the impression, which involves a plaster bandage negative being produced. This negative is then turned into a plaster positive mould whereby a plastic shell can be vacuum formed over, to produce the individualised plastic shell; and one visit for the fitting where side attachments are fitted, followed by the computed tomography (CT) simulation. This process can take up to several days. See Figure 4.

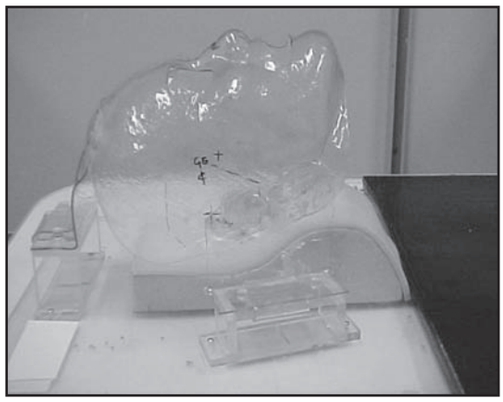

Figure 4: Westmead Hospital Radiation Oncology Rigid Plastic Cast.

Thermoplastic Casts

Thermoplastic casts (commonly referred to as Orfit) are made of an opaque sheet material. Each cast can be produced quickly by heating the pre-cut thermoplastic sheet and moulding it over the patient's head and face. This can be carried out prior to, or during the simulation session, thereby reducing the visits and waiting time for radiotherapy. See Figure 5.

Commencement of radiotherapy at the earliest opportunity is vital, as stated by Do,V et al (2000) in their study of high grade gliomas.[3] The waiting time from presentation at a radiotherapy department until treatment is a significant predictor of overall survival for patients with high grade gliomas, with an increased risk of death by two per cent per day while waiting for radiotherapy,[3] thus demonstrating the time factor required for the construction of thermoplastic and rigid plastic casts must be considered seriously.

Another consideration with masks is that they can lead to build up of dose on the skin, however the field area can be cutout to avoid this.[13] Masks may be used regardless of dental status. The tight fitting thermoplastic mask is initially warm on production and can be very uncomfortable for claustrophobic patients, as it is opaque. Thermoplastic masks have a significantly worse repositioning accuracy therefore it is less suitable for precise positioning required to treat tumours surrounded by critical tissue, as demonstrated by the stereotactic frame.[2,3]

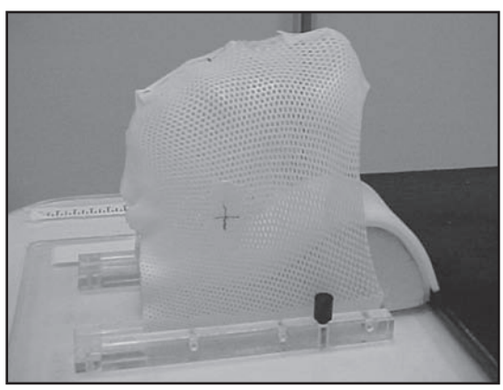

Figure 5: Westmead Hospital Radiation Oncology Thermoplastic Cast.

Bite Blocks

Bite blocks have been shown to have better immobilisation capabilities than masks,[4] but are limited to patients with no tumours of the hard palate. They are rigid and taste bitter, but are relatively pain free.

The Vogele Bale Holmer (VBH) Head Holder is a form of a bite block immobilisation system. It is based on an individual vacuum dental cast connected to a head plate via two hydraulic arms.

Precise positioning is paramount as tumour doses increase and target volumes decrease, becoming conformal. A variation of delivered target dose should be no more than 3.5 per cent.[5]

METHOD

A literature search was conducted to compare methods and statistical deviations between various immobilisation methods. The literature search and review was carried out using the following computer search engines; science direct, medline and cinahl, from 1966-2001. The search keywords used included: stabilisation, radiotherapy, brain, conformal, orfit, uvex, cast, masks, patient fixation, Vogele Bale Holmer (VBH) Head Holder and bite block.

Literature Review

Imaging and machine limitations, including physical attributes of the patient, for example, age and physical health, together with the experience of the therapists are all factors that influence the accuracy of treatment delivery. These limitations should be kept in mind when designing regimes of immobilisation devices, target volume placement, and treatment techniques.[7]

The most recent brain immobilisation device introduced at Westmead Hospital is the stereotactic frame. As stated in the introduction there are two major types of stereotactic frames available, invasive also known as fixed frames and non-invasive also known as relocatable.

Burton, KE et al (2002) conducted a study of thirty one (31) patients, whose conditions included meningiomas and metastasis and were treated using the GTC relocatable head frame. Measurements were taken at each planning, verification and treatment episode for the three directions of movement anterior/posterior, lateral, and superior/inferior. For each measurement, the displacements in all directions were calculated using simple trigonometry.

Those patients with severe anxiety, motor and sensory deficits, had difficulty cooperating in the study, thus demonstrating the need for selecting appropriate patients for use with this system. The results show a minimal variation allowing a 3mm margin between clinical tumour volume (CTV) and planning tumour volume (PTV) for fractionated stereotactic radiosurgery (SRS)[KW3], taking into account the variance produced by different radiation therapists measuring and fitting the depth helmet. For single fraction SRS, the accuracy of relocation was assessed prior to the treatment, therefore a minimum margin between CTV-PTV could be used.[1]

Zhu, Y. et al (2000) conducted a study of paediatric brain tumours using fixed frame and vacbags for comparison. Twenty two patients were selected, age range from 2-11 yrs. Twelve patients were fitted with head frames and those under 5 yrs were generally fitted with a vacbag. The patients treated with vac bags were treated either supine or prone depending on the tumour site, they also required sedation/general anaesthetic. Patients treated in the relocatable head frame were treated supine.[8]

Alignment of the patient was achieved by marking the skin and immobilisation device during simulation, alignment was checked prior to treatment, the couch position was recorded and the patient position was verified by using DRRs and portal films as a pair. e.g. lateral digitally reconstructed radiograph (DRR) and lateral port film. The results for the 12 head frame patients indicate that the overall standard deviation in the lateral direction was 3mm, superior-inferior direction was 2.4mm and the ant/post direction was 2.2mm. The mean overall 3D error being calculated at 4.4 mm. The overall standard deviation for the 10 vacuum bag immobilised patients were as follows 3.2mm in the left-right direction, 3mm in the superior-inferior direction and 3.3mm in the AP direction. The mean overall 3D error being calculated at 5mm.[8]

Schulte, R et al (2000) compared two systems, thermoplastic masks and bite blocks attached to a stereotactic frame. Both techniques showed similar immobilisation efficiencies though results may be biased, as patients were aware of the study, therefore conscious of their motion. When comparing the standard mask to the dental fixation method, they found similar amounts of intra-treatment movements. Not addressed in this study, but acknowledged, is that the total positioning error is made up of motion and re-positioning error. The results of the study show that most patients are able to maintain their position prior to and during radiotherapy treatment to within, less than or equal to 1mm.[9] The total treatment time and the subjective presence of discomfort has little influence on the amount of movement.[9] The study states that more patient data would be useful to confirm these statements.[9]

The simultaneous use of internal, for example, oral organs and external fixations can create an incredibly reproducible immobilisation device. The VBH is rigidly fixed and pain free, which is accurate and reproducible.

The VBH holder would only need repositioning should the patient's upper dentition change or an error occur with the system itself. The VBH holder cannot be used for tumours of the hard palate, and patients must be able to open their mouth. A double dentition tray can be used if there is a need to stabilise the lower jaw.[4] The head holder has been found to have submillimetric accuracy with a case report submitted by Sweeney et al (1998) showing a repositioning accuracy of 1.02mm while that of a thermoplastic mask was 3.05mm.[4]

Bite blocks assist the internal fixation of organs and also assist in the external immobilisation of the head region. Willner, J. et al (1997) analysed the 3 Dimensional reproducibility of the isocentre and patient positioning with the usage of the bite block. A simple verification system was used with complex beam arrangements for Ear Nose and Throat tumours. Twenty nine patients were analysed for a total of 136 treatment sessions, all patients were immobilised using individual bite blocks and head and neck supports. During simulation the isocentre was marked on the patient's skin and orthogonal films taken. Four to six pairs of orthogonal verification films were taken during treatment.

The analysis showed that random and systemic deviations in the 3 directions are in the range of plus or minus 4mm, 2 Standard Deviations, comprising of 95 per cent of the deviations, and are within the range as described in this literature review.[10] As previously noted these deviations should be taken into account when the Planning Tumour Volume is defined.

Unlike the stereotactic headframes employed in the past ten years at Westmead Hospital the traditional immobilisation devices in the form of rigid plastic and thermoplastic casts have been used since 1979 and 1989 respectively and are all non-inva-

sive. These are more comfortable and can be used with the advance of technology such as Intensity Modulated Radiation Therapy.[3]

Generally, immobilisation techniques have focussed on fixation of anterior structures, with less attention on the supports under the head and neck region. Bentel, G et al (1995) completed a study with 24 patients, 18 patients with customised headrests in a comfortable neutral position, and six patients using a standard headrest. The base plate was made of expanded Styrofoam and the mask from Orfit perforated thermoplastic material, which is then firmly attached to the base plate. All patients removed clothing above the waist, as the immobilisation device conforms very closely to the patients' anatomy. The headrest should provide support under the inferior aspect of the neck and upper thorax, which is important in ensuring reliable positioning of the cervical spine. The shape of the customised headrest conforms to provide support under the inferior aspect of the neck and upper thorax assuring reliable positioning of the cervical spine.[11]

Bentel et al (1995) measured the difference in the contour shape of a standardised head and neck support and compared them to the contour shape of the customised head and neck supports used in the study. This study found that the height under the neck region of custom supports varied from 5.8 to 9.8cm in comparison to 5 to 8cm for standardised head supports.[11] The comparison of the head region was similar, 3.2 to 6.2cm for the customised variety and 1 to 5cm for the standard head rest.[11] These measurements show a significant difference which can have an impact on comfortable and accurate positioning.

The headrest shape used can alter significantly the neck position, thereby altering the position of the anatomy, therefore careful consideration should be used when determining the neck position and the target volume.[11]

Hess, C. et al (1995) conducted a study of the Orfit masks' systemic errors. These errors affect the overall quality of the treatment and can be detected with the first check film. They found the transfer from the simulator to the machines did not significantly contribute to the measured discrepancies. The deviations between simulator and treatment were less than 3mm anterior to posterior, but 9mm superior to inferior.[12] Deviations between right and left side treatment were equal to or less than 1.3mm ant/post and 5.3 mm sup/inf, and the deviations between original film and boost film were equal to, or less than 2.9mm and 12mm.[12] The ninety-five patients were not randomly picked. Series of verification films can be analysed for patients with tolerance discrepancies, such as couch position, head position, and gaps between the skin and cast. Even with daily electronic portal imaging, it is extremely difficult in clinical routine to confidently define quantitative levels for a corrective action.[12]

Rigid plastic masks that are cut out are more expensive due to multiple mask production required for boosts and the labour and staff costs involved, but the skin-sparing effect is beneficial to the patient, but masks that are not cut out, are not as expensive as cut out masks, but more expensive than the thermoplastic masks. The cost of staff plus time of the staff in producing the masks impacts significantly on department resources as well as recurrent cost of material for the production of cut out rigid plastic masks.

Weltens, C et al (1995) suggests that Orfit masks that are cut out are cheaper than Uvex but this could affect the rigidity of the mask. There was no difference detected in the immobilisation.[13] The standard deviation is approximately 2mm and no day-to-day variation of more than 10mm was detected. The combination of thermoplastic masks and bite blocks demonstrates a mean motion of 2mm. Weltens, C et al (1995) show that there was no difference between thermoplastic and rigid plastic, however, cut outs restrict the field border definition and rigidity, therefore the need for secondary masks for successive phases has to be addressed.[13]

DISCUSSION

The stereotactic frame is fixed and rigid, with a 3D displacement of 0.5 mm. The positioning of both the fixed and relocatable stereotactic frames becomes time consuming especially if the treatment is administered for several fractions. Additionally due to the expense Westmead Hospital uses the frames for stereotactic treatments only.

A comparison of Orfit and Uvex masks demonstrated identical precision in immobilisation of the patients' head, although the non-transparency could be a disadvantage of orfit.[13] A huge advantage of Orfit casts is their reusability and speed of production.Though Orfit remains the cheapest solution, this factor is dependent on the number of patients that require Orfit casts and the number of times a cast can be reused. Therefore we need to assess which is more suitable, the higher cost of Orfit, which offsets its cheaper production, or the initially more expensive plastic mask.[13]

Customised head and neck supports are beneficial, as they are more comfortable, therefore less patient movement, plus removal of clothing from the waist upwards is important.[11] A difference as subtle as a difference in clothing can cause the mask to be either too tight or too loose. Therefore custom made head rest support show an improvement over the standard head and neck supports, as the anatomy of most patients do not conform well with standard supports. Custom headrests conform to the entire posterior surfaces of the patients' head, neck and upper thorax area, providing improved fixation. Patients are more comfortable with customised supports therefore, are less likely to move.[11]

Immobilisation systems themselves are likely to affect the accuracy; some materials are soft and supple, for example, thermoplastic, while others are rigid and stiff, for example, rigid plastic, bite blocks and SRS frames. Should facial contours change during treatment, the mask may not fit causing inaccurate positioning therefore repeat production and localisation may be necessary.[4] Thermoplastic mask fixation in spite of easy and quick repositioning has a significantly worse accuracy of repositioning and is less suitable for radiotherapy where accuracy is paramount due to the proximity of critical organs.[4]

Additional to the Orfit and Uvex mask systems employed at Westmead Hospital, the VBH head holder examined by Sweeney et al (1998) offers a reproducible fixation method with sub-millimetric accuracy. This method can be employed for brachytherapy Ear, Nose and Throat (ENT) surgery, neurosurgery and radiosurgery.

CONCLUSION

The review showed the advantages and disadvantages for all types of immobilisation devices. Non-invasive immobilisation systems avoid the cost of a surgical procedure, thus reducing the risk of infection. Quick release systems reduce patient discomfort.[1] Uncut Uvex casts have no advantage over Orfit casts. The cut casts may have a skin-sparing effect; this is offset by the limitations as to where the field marks can be placed. Most immo-

bilisation masks focus on the movement of anterior structures, but they should provide support to the inferior aspect of neck of thorax that gives positioning to the cervical spine.[11]

The bite-block is a simple method of immobilisation, but more research is needed to compare it to other techniques already used. Research is required into using this system with our current and future imaging and planning techniques.[14]

From our literature review, we cannot produce a definitive answer, as certain variables should be considered. These variables stem from a range of areas, from the radiation therapist's experience at certain techniques, to the patient compliance and imaging techniques. No system is preferential over the others until these variables have been taken into account. However, random and systemic deviations are in the order of plus or minus 4mm as quoted by Wilner, J. et al (1997). These deviations should be taken into consideration when planning target volumes. Further direction could be undertaken in the form of research into organ motion, bite blocks, tumour motion, imaging advances and limitations for normal tissue complication probabilities and tumour control probabilities with the advances of IMRT and SRS.

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