Technical Note

A New Headholder for PET, CT, and NMR Imaging

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Abstract: A new headholder was developed for patient restraint and repositioning during positron emission tomography (PET), CT, and nuclear magnetic resonance (NMR) imaging procedures. A customized form was produced for each patient by pouring polyurethane resin and catalyst between an injection-molded polystyrene shell and a protective latex sheet and placing the patient's head in the form while the resin set. Excellent head restraint and repositioning was achieved when the headholder was used with a crossed-laser system. Repositioning accuracy was demonstrated by comparing transmission scans of the same patient obtained on different days and by comparing PET transmission scans with coplanar CT scans. No artifacts due to the headholder were apparent in CT, PET, and NMR images. Index Terms: Computed tomography, apparatus and equipment—Emission computed tomography—Nuclear magnetic resonance.

Precise patient repositioning is required for correlating information provided by different imaging modalities [e.g., positron emission tomography (PET), CT, and nuclear magnetic resonance (NMR)] or studies performed using the same modality (e.g., enhanced and nonenhanced CT and PET blood flow and oxygen metabolic studies), comparing studies performed at different times (e.g., before and after therapy or during long-term follow-up), for implementing special corrections (such as tissue attenuation or blood volume corrections for which additional measurements are needed), and for planning radiation therapy based on diagnostic CT. The ideal headholder should (a) permit precise long-term as well as short-term repositioning, (b) minimize patient motion during scans, (c) allow indexing with some anatomical reference, (d) be easy and rapid to manufacture, (e) afford maximum patient comfort with minimal invasiveness, (f) not restrict patient vision or hearing, (g) minimize attenuation and artifact, (h) be relatively inexpensive, (i) be reusable, and (j) be useful for a wide variety of imaging modalities.

A number of repositioning and restraining devices and techniques have been reported in the literature for diagnostic applications (1–9). This paper will report on a new repositioning/restraining device for neurological diagnostic imaging which utilizes a polyurethane foam similar to that employed for radiotherapy immobilization (10–12).

MATERIALS AND METHODS

A customized headholder may be manufactured within 20 min for individual patients. An injection-molded polystyrene shell, designed to accommodate most head shapes and sizes and to fit into a number of existing scanner headrests (including Picker, Oldeft, AECL, and most Technicare and GE headrests), is wrapped in a latex sheet, which acts as an insulator and restrains the materials. The shell is then placed into the couch headholder. Polyurethane resin and catalyst are mixed together and poured between the sheet and the shell. After 2–3 min, the patient's head is positioned in the shell. An exothermic reaction takes place as the resin cures, and the temperature rises to approximately 105°F at the foam surface. The foam, which expands to approximately 20–30 times its original volume, fills the space between the shell and the

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latex cover, and the cover becomes taut. A Velcro strap is used to restrain the patient’s head for 5 min after the addition of catalyst. The foam cools and hardens into a rigid polyurethane mold of the patient’s head, which holds its shape indefinitely. A hack saw or circular saw may be used to cut holes in the sides of the headholder to expose the external auditory canals for laser alignment and to permit the use of earphones for neurobehavioral stimula-

FIG. 3. Eight axial planes of an $^{82}$Rb/positron emission tomographic study obtained before (upper eight images) and after (lower eight images) cerebral angiography in a patient with metastatic brain tumors. Note the excellent repeat axial and transverse registration of normal and tumor anatomy.

FIG. 2. Positron emission tomographic transmission scans of DeltaScan 2020 couch headholder: by itself (top left), with new headholder (top right), with solid thermoplastic face mask (Polyform) (bottom left), and with mesh thermoplastic face mask (Aquaplast) (bottom right).

tion studies. Indexing marks may also be made on the polystyrene shell for patient repositioning, in conjunction with a crossed-laser system.

A patient headholder was placed in the Technicare DeltaScan 2020 couch headrest of the PC 4600 Neuro-PET and a transmission scan was performed using the $^{68}$Ge/$^{68}$Ga rod source (13). Transmission scans of the empty Lucite headrest and two masks manufactured of low-temperature thermoplastics (solid Polyform and mesh Aquaplast) used for radiation therapy immobilization were also obtained for comparison. Special headholders (somewhat thicker than those employed for patients) were made for an 18 cm diameter, 15 cm long uniform water-filled phantom and a “hot spot” resolution phantom (14). To measure the attenuation of the headholder and to determine if it gave rise to any scan artifacts, these phantoms were placed in their headholders, filled with a solution of $^{68}$Ga, and scanned in the PC 4600 Neuro-PET. The same phantoms were filled with water and scanned in a DeltaScan 2020 using standard head technique (120 kVp, 37 mA, 8 s) and subsequently filled with a manganese sulfate solution (approximately 0.1 mM) and scanned in the head coil of a Technicare 0.5 T Teslacon NMR scanner. Spin-echo sequence with several echo times (TE = 30 and 60 ms) and several repetition times (TR = 500 and 1,500 ms) were used.

To test the short-term repositioning capabilities of the new headholder/crossed-laser system, scans obtained from a patient imaged with $^{82}$Rb and the PC 4600 Neuro-PET immediately before and 1 h after cerebral angiography were compared. The
NEW HEADHOLDER FOR IMAGING

FIG. 4. Demonstration of achievable repositioning accuracy possible with the new headholder and a crossed-laser system. Top left: Positron emission tomographic (PET) transmission scan on day 1. Top right: PET transmission scan 42 days later. Bottom left: difference image. Bottom right: ratio image.

FIG. 5. Examples of coplanar positron emission tomographic transmission and CT scans of a patient positioned using the new headholder and a crossed-laser system.

long-term repositioning capabilities of the system were examined by creating ratio and difference images of transmission scans obtained from the same patient on different days. Several patients were carefully positioned using the headholder/laser systems, and transmission scans were obtained on PC 4600 Neuro-PET and, subsequently, on the DeltaScan 2020 CT scanner.

RESULTS AND DISCUSSION

A completed headholder, which was cut for placement of earphones for PET neurobehavioral studies, is illustrated in Fig. 1. To date, headholders have been made for more than 30 patients who underwent multiple PET examinations. Although some motion is possible, the head always returns to its natural, most comfortable position (that for which the headholder was cast). This, together with the fact that the patient’s face is not covered by the headholder, resulted in excellent patient acceptance. No motion artifacts were observed during PET (lasting as long as 2 h) or CT.

The minimal attenuation of the headholder is apparent in Fig. 2, which shows transmission scans of the scanner headrest and the new headholder made with a $^{68}$Ge/$^{68}$Ga source and the PC 4600 Neuro-PET. The headholder is invisible in these scans, although the headrest and two thermoplastic face masks are clearly seen. For PET of the phantom filled with $^{68}$Ga solution, the headholder was found to attenuate $<1.4\%$ of the total counts, compared with 4–13% attenuated by the DeltaScan 2020 scanner headrest. The use of an experimental attenuation correction adequately compensated for these losses. The CT number of the headholder was observed to be $-948$ HU with the DeltaScan 2020, compared with $-1,000$ HU for air. For NMR imaging with the Technicare 0.5 T Teslacon, the headholder was indistinguishable from background (typical signal number $= 600 \pm 300$) even when a low contrast phantom (signal/noise $= 23$) was used to outline the inner circumference. No artifacts were noted in PET emission or transmission, CT, or NMR scans of the phantoms and patients with the headholder.

Laser repositioning has been observed to be accurate to within $<2$ mm (8). Eight axial planes from $^{82}$Rb/PET studies performed before and after cerebral angiography are shown in Fig. 3, which demonstrates the short-term repositioning accuracy achievable with the headholder. Figure 4 shows two PET transmission scans of the same patient taken 42 days apart. The difference and ratio images demonstrate the excellent long-term repositioning accuracy that can be achieved. The correlation between PET transmission and CT scans in the same patient positioned using the new headholder is illustrated in Fig. 5 for two brain sections.

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CONCLUSIONS

Our polyurethane headholder system is easy to manufacture, comfortable for the patient, and has practically no effect on PET, CT, and NMR scans. Excellent short-term, long-term, and cross-modality repositioning is possible when it is used in conjunction with a crossed-laser system.

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