Head Movement in Normal Subjects During Simulated Brain Imaging

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Objective: Videotape images of 30 volunteers were used to classify and measure head movements that may occur during brain imaging.
Methods: A simple videotape setup was designed to record simultaneously the lateral and vertex views of the subject's head. Volunteer subjects were positioned for brain imaging and their heads were videotaped for 2 hr. Head movement was identified and measured.
Results: All subjects demonstrated angular movement within the transaxial plane (rotation of the head). There was angular movement in the sagittal plane and translation of the transaxial plane. There was no movement of the coronal plane, nor was there any translational movement of the sagittal plane.
Conclusion: The most dominant head movement was rotation. The effects of other factors such as height, weight, age, smoking habits, and caffeine and alcohol intake could not be determined with this sample size.
Key Words: head movement; motion artifact; brain imaging

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SPECT and PET nuclear medicine imaging play important roles in diagnosing and managing several neurological diseases and disorders (*1–4*). The acquisition times for these studies vary between 1/2 hr and 3 hr. A typical PET brain scan using ^{18}F-FDG takes approximately 2 hr at the Austin and Repatriation Medical Centre, Melbourne (Fig. 1). A PET study of the brain, using ^{18}F-FDG to examine glucose metabolism, consists of many phases. First, a rectilinear scan is performed to ensure that the area of interest is located within the field of view. This phase may not be necessary if the axial field of view is larger than the PET system used in this example (*5*). Second, a transmission scan is performed to provide attenuation correction data for each patient's brain and skull. The ^{18}F-FDG is administered intravenously and is followed by a wait of between 30 and 45 min, which is required for the ^{18}F-FDG to accumulate in the cells. Finally, an emission acquisition of about 30 min is performed. Thus a PET brain study using ^{18}F-FDG and all of these elements may take up to 120 min. Clearly this is a long time for the patient to remain still. The possible head movements that may occur during this time are translational and angular movements in each of the three anatomical planes (*6*). This head movement has the potential to degrade image quality (*7*). The acquisition time for SPECT has been reduced, to some extent, by the use of triple-headed gamma cameras. A reduction of acquisition time for PET is possible using three-dimensional acquisition but this technology is not used routinely (*8*).

Head movement during these prolonged acquisition times and the resulting image degradation are still issues that must be investigated and controlled if the true potential of SPECT and PET brain imaging techniques is to be realized. The aim of this investigation was to classify and quantify the major head movements that can occur during brain imaging. The effects of other factors such as height, weight, head circumference, smoking, caffeine and alcohol consumption, comfort and sleep also were considered.

MATERIALS AND METHODS

The study population comprised 30 volunteer subjects, 10 males and 20 females with a mean age of 41.03 yr, ranging from 14–61 yr. Head circumference, height and weight for each volunteer was measured. Details of the smoking habits and caffeine and alcohol consumption of each subject were recorded.

Each subject was positioned supine as for a routine PET or SPECT examination of the brain, but without any head restraint. The equipment used was the standard bed and acrylic head holder supplied with a commercially available PET scanner. The subject was made as comfortable as possible. Pillows were placed beneath the knees to provide support for the lumbar spine with a minimum of two pillows, and a maximum of four, depending on the height of the patient. A support roll was placed below the curvature of the neck and a foam pad was positioned under the head to cushion the occiput. A strap to support the arms was offered to each subject but only two subjects chose to use it. Details of the position of each subject were noted. Each subject was given a few minutes to settle into

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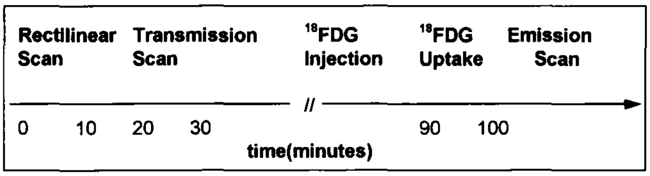

FIGURE 1. Timeline depicting all the elements and their durations for a PET ^{18}F-FDG brain study.

position before beginning the videotape. The subjects were not necessarily positioned with the sagittal plane perpendicular or the coronal plane horizontal as this alignment of the anatomical planes could be done using the positioning lasers and the angulation of the detector gantry during the actual brain imaging procedure. Some subjects were asked to wear a disposable surgical cap to ensure that the nose was visible in the vertex view. A mirror was positioned at 45° to the midsagittal plane to enable both vertex and lateral images of the subject's head to be recorded simultaneously (Fig. 2).

Each subject's head was imaged and recorded for a 2-hr period using a videocamera recorder/player and a 1-hr VHS-C tape and the long-play facility. The time period of 2 hr was selected as this is the average time required for a PET brain scan as described in Figure 1.

The images taken by the videocamera were transferred to VHS videocassettes using a videocassette recorder (VCR) with freeze-frame capabilities. The video images were analyzed using the VCR and a 51-cm color television and acetate sheets (Fig. 3). The acetate sheets were attached to the television screen, one sheet for each of the vertex and lateral images. The horizontal and vertical positions of the tip of the nose, the external auditory meatus (EAM) and the outer canthus (OC) were marked using a black, permanent overhead transparency pen. All three landmarks were marked on the lateral view and the tip of the nose was marked on the vertex view (Fig. 3). The videotapes were viewed for their duration. Each minute, if movement had occurred, the new position of the landmarks was marked using a different color, permanent overhead transparency pen. The time of the movement and the type and direction of each movement were noted.

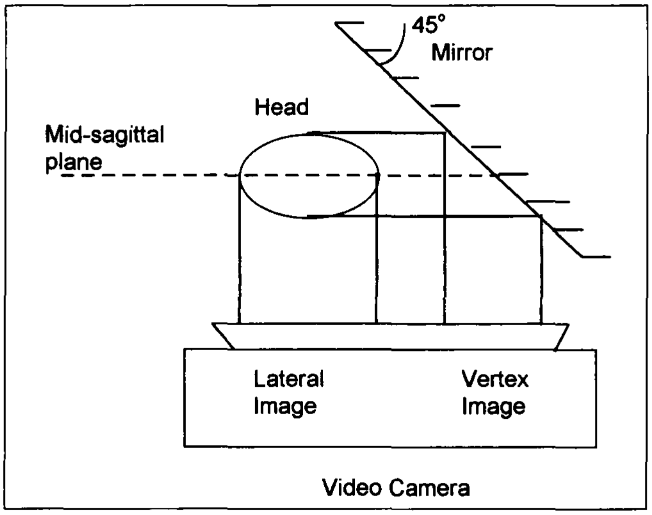

FIGURE 2. Diagram of the relationships among the head, videocamera and mirror which allowed the vertex and lateral images of the head to be acquired simultaneously.

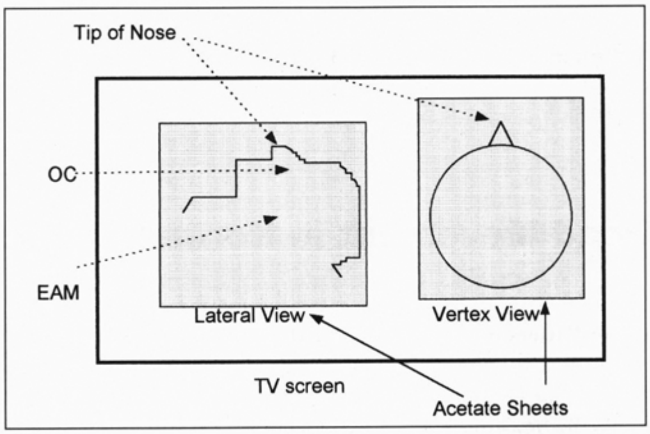

FIGURE 3. Diagram of the television monitor showing the vertex and lateral images of the head. The placement of the acetate sheets and the landmarks are indicated.

The acetate sheets were removed from the television after the videotape had been viewed and the positions of the landmarks noted. The various positions of the landmarks were examined and the movements were classified and measured as angular or translational in each of the three anatomical planes. Movements were identified and classified using the positions of the three landmarks indicated on Figure 3 and the information in Table 1.

The extent of the translational movement was measured in millimeters. Angular movement was measured in degrees. The angle measured for the transaxial plane was based on the inferior border of the skull, as depicted on the video images.

TABLE 1

Combination of Landmark Movements Used to Identify the Type of Head Movement that Occurred

	Vertex	Lateral		
Type of Movement	Nose	External auditory meatus	Outer canthus	Nose
Sagittal plane				
Angular	N	N	H and V	H and V
Translational	V	N	N	N
Coronal				
Angular	N	N	H	H
Translational	V	V	V	V
Transaxial				
Angular	H and V	V	V	V
Translational	N	H	H	H

N = no movement; H = horizontal movement relative to bed; V = vertical movement relative to bed.

TABLE 2
Percentage of Subjects Exhibiting Angular or Translational Movement

Plane	Type of movement	
	Angular	Translational
Sagittal	69%	0%
Coronal	0%	0%
Transaxial	100%	72%

The angle for the sagittal plane was measured at the EAM. Actual distances moved were calculated using the head holder to calibrate the video images. The length of the head holder was used for the lateral images and the width was used for the vertex images. The points marked to measure these distances also were used to minimize the parallax error when viewing the video images on the television screen. Movements of less than 60 sec duration were ignored unless they were repetitive or rhythmical, such as those that may occur with respiration.

Periods of sleep were noted. This was based on feedback from the subject, who was asked at the conclusion of the 2-hr period if they had fallen asleep, and on visual observation of the videotapes for rhythmical motion of the chest which was used as an indicator of sleep. Subjects were asked for feedback on their general comfort. For example, providing information regarding which part of their body was aching the most, or in which area of their body they felt the most pain, and what, if anything, could have been done to make the time less stressful or more comfortable.

RESULTS

All subjects demonstrated some movement. The time of the various movements was spread throughout the 2-hr period. The most significant feature observed was the total absence of translational movement of both the coronal and sagittal planes and of angular movement in the coronal plane. One subject was unable to complete the total time period due to pressure on the occiput causing discomfort. This subject has been excluded from the movement analysis. The most prevalent movement was the angular movement in the transaxial plane (rotation of the head to the right or left), with all subjects exhibiting some degree of head rotation. Twenty subjects (69%) exhibited angular movement in the sagittal plane, in other words flexion/extension, and 21 subjects (72%) exhibited translational movement of the transaxial plane. These results are summarized in Table 2.

Rotation, as can be seen in Figure 4, is not only the most prevalent movement, but is also the movement that produced the most displacement. This is confirmed by the data in Table 3. All subjects exhibited a displacement of > 4 mm of angular movement in the transverse plane (rotation) while angular movement in the sagittal plane (flexion/extension) and translational movement of the transverse plane, were both > 4 mm for 14 subjects (48%). The three subjects who exhibited rotational movement of > 30 mm all slept for more than 90 min. A total of eight subjects slept for this length of time but the rotational movement did not exceed 16 mm in the other five subjects.

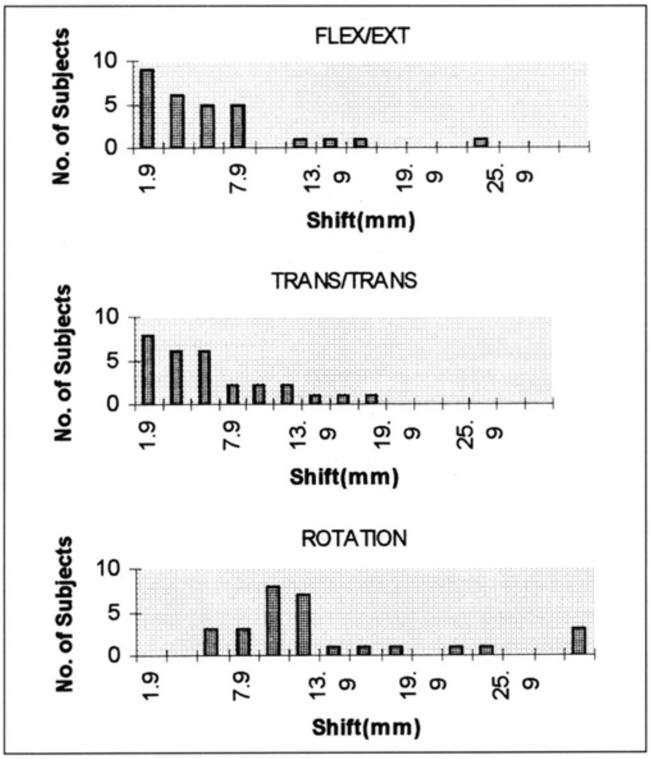

FIGURE 4. Graphs showing the number of subjects versus the amount of displacement for each of the three movements identified and measured.

The data were plotted to see if any one type of movement was dependent upon or influenced by the degree and type of another movement. Figure 5 indicates that such a relationship could not be demonstrated.

The height, weight and head circumference of each subject were measured. The data were analyzed to see if there was any relationship between age (range 14–61 yr) or head circumference and the type and amount of head movement. The average head circumference was 55.75 cm with a minimum of 52 cm and a maximum of 61 cm. No such relationship could be demonstrated with this sample size.

The height and weight were used to broadly categorize the stature of each subject. The resultant ratios and classifications are depicted in Table 4.

TABLE 3
Average Angular or Translational Displacements

Plane	Type of movement	
	Angular displacement	Translational movement
Sagittal	2.8° (0–14°)	0.00 mm
Coronal	0.00°	0.00 mm
Transaxial	4.9° (1.5–21°)	4.98mm (0–16.50 mm)

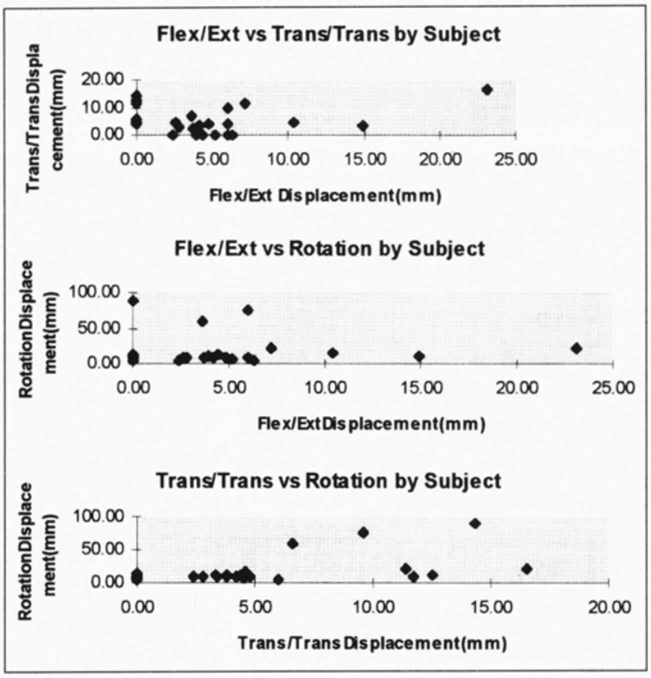

FIGURE 5. Graphs depicting each movement that was identified and measured.

All subjects commented on a general stiffness at the conclusion of the 2-hr period and 12 remarked that they felt a marked stiffness across their backs between their shoulder blades.

Six subjects had consumed alcohol in the hour immediately before beginning the videotaping. The head movements for this group and those subjects who had not consumed any alcohol are shown in Table 5.

There was only one subject who smoked. Caffeine was consumed by 24 of the subjects on a regular basis. Sixteen subjects consumed less than four cups of tea or coffee per day. The maximum tea or coffee consumption was one subject with 12 cups per day. There was no evidence to show there was a relationship between head movement and caffeine consumption.

DISCUSSION

The 2-hr time period for the analysis of head movement was based on the requirement for the PET brain study as described in Figure 1. This is only an example as there are many applications of SPECT and PET where the imaging time could exceed this.

TABLE 4
Height/Weight Ratios and Resulting Stature Classification

Height/Weight	Stature	Number of subjects
>3	Slight	4
2.5–2.9	Medium	15
<2.5	Heavy	10

Angular and translational movement of each of the three anatomical planes was examined. The lack of translational movement of the sagittal and coronal planes could be due to the fact that these movements require a greater amount of concentrated effort and would not be accidental movements. Translational movement of the coronal plane, for example, requires the subject to raise their head vertically and completely from the head support. This movement would be difficult without a conscious effort. The absence of angular movement within the coronal plane could indicate that this movement is somewhat inhibited by the shape of the head holder. The minimal translational displacement of the transaxial plane could be attributed to the placement of pillows beneath the knees. The absence of a push-off point, in other words with the heels on the bed, reduces the possibility of the body position changing and moving the head in this way.

The degree of rotation, demonstrated both in terms of the number of subjects who exhibited this movement and the amount of displacement that occurred, indicates that this movement is most likely to cause degradation of image quality.

The lack of a relationship between each of the movements identified and measured, as shown in Figure 5, would mean that restricting one of these movements will not have any effect on the amount of other movement which may occur.

The effect of age and head circumference cannot be clearly stated at this point. Another study including more subjects at either end of the age range would need to be completed before any conclusions on the relationship between age and head movement could be reached. Similarly another study with additional subjects with head circumferences at each end of the spectrum would need to be studied before making any recommendations about the relationship between the size of the head and the degree of head movement.

The stiffness across the back of the shoulders was most likely due to the curvature of the PET scanning bed. Ten of the subjects were classified as having a heavy stature and being broader across the shoulders and these subjects tended to feel this stiffness more. Consideration should be given to the use of a flat scanning bed. This also would allow better correlation of patient positioning with radiation therapy where a flat bed is used.

The results depicted in Table 5 do not indicate any significant effect of alcohol on head movement, although there is a slight increase in the degree of rotation exhibited by these subjects. There also was no evidence to show any relationship between head movement and caffeine consumption.

The analysis of the data for a relationship between period of sleep and head movement does not provide any clear evidence that such a relationship exists.

CONCLUSION

The major head movement that was identified during this investigation was angular movement within the transverse plane or rotation of the head. Angular movement within the sagittal plane and translational movement of the transverse plane do not occur in all subjects nor do they happen to the

TABLE 5
Average Angular or Translational Displacements for Subjects Consuming Alcohol within 1 Hour of Beginning Videotape (Group A) and Subjects Having No Alcohol (Group B)

Plane	Type of movement: Angular displacement		Type of movement: Translational movement	
	Group A	Group B	Group A	Group B
Sagittal	2.3° (0.0–4.0°)	2.9° (0.0–8.5°)	0.0 mm	0.0 mm
Coronal	0.0°	0.0°	0.0 mm	0.0 mm
Transaxial	5.6° (1.5–33.5°)	4.7° (1.5–20.5°)	2.95 mm (0.0–14.3 mm)	5.5 mm (0.0–16.5 mm)

same extent as angular movement within the transverse plane. These factors should be considered when placing head restraint devices in position, with particular attention being paid to the restriction of rotational movement of the head.

The effects of other factors on head movement, such as height, weight, head circumference, smoking, caffeine and alcohol consumption, and periods of sleep, could not be demonstrated at this stage.

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REFERENCES

1. Ell PJ, Costa DC, Cullum ID, et al. *Ceretec rCBF atlas: the clinical application of rCBF imaging by SPET.* Amersham Place, Little Cholfort: Amersham International Plc; 1987.
2. Phelps ME, Hoffman EJ, Huang SC, et al. ECAT: a new computerized tomographic imaging system for positron-emitting radiopharmaceuticals. *J Nucl Med* 1978;19:635–647.
3. Tilyou SM. SNM newsline. Yesterday, today, and tomorrow: the evolution of positron emission tomography. *J Nucl Med* 1991;32:15N–26N.
4. Wagner HN Jr. Clinical PET: its time has come. *J Nucl Med* 1991;32:561–564.
5. Egan GF, McKay WJ. Current status of Positron Emission Tomography Centre at the Austin Hospital. *ANZ Nucl Med* 1991;22:16–17.
6. Seeley RR, Stephens TD, Tate P. *Anatomy & Physiology*, 2nd ed. St Louis: Mosby Year-Book;1992:308–311.
7. Bice AN, Keller PJ, Drayer BP. Simulation analysis of movement induced artifacts in neurological PET. *Abstracts of the IEEE 1993 Nuclear Science Symposium and Medical Imaging Conference*, San Francisco: IEEE;1993:142.
8. Cherry SR, Dahlbom M, Hoffman EJ. 3D PET using a conventional multislice tomograph without septa. *J Comput Assist Tomogr* 1991;15:656–668.