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A survey of nuclear cardiological practice in Great Britain

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on behalf of the British Nuclear Cardiology Group

Abstract

There is little information on the practice of nuclear cardiology in Great Britain. On behalf of the British Nuclear Cardiology Group in October 1988 we sent a postal questionnaire to 143 hospitals with nuclear medicine facilities (at least 70% of such hospitals). Sixty nine replies were received (48%), of which 23 (33%) were from teaching hospitals and 46 (39%) non-teaching. In these hospitals 147 904 isotope investigations were performed annually (mean 2311 per centre) of which 17 298 (12%) (mean 254 per centre) were cardiac studies. Of these, 59% were equilibrium radionuclide ventriculograms, 14% first pass ventriculograms, and 27% thallium-201 scans. Rest studies were performed more commonly by radiographers or technicians (63%) than by doctors (20%), but doctors were more commonly involved in stress studies (48%). Radiologists reported the studies more often (28%) than they performed them (6%). Methods of acquisition and analysis were varied and, for instance, the lower limit of normal left ventricular ejection fraction ranged from 35% to 75% (mean 49%). For thallium imaging 42% of centres used dipyridamole in some patients and 24% used tomography.

These data show that nuclear cardiology techniques are used much less frequently in Great Britain than in countries such as the United States and Germany, that the ratio of blood pool to myocardial perfusion imaging is much higher than elsewhere, and that methods are poorly standardised. They may provide the impetus to improve the service and serve as a baseline for future surveys.

The role of nuclear medicine in patient management is increasing because of the importance of the functional information that it provides.[1] The number of nuclear medicine publications listed in *Index Medicus* has increased rapidly since 1977. At the most recent meetings of the American Heart Association and the European Congress of Cardiology just under 10% of the abstracts reported work with isotope techniques. Thus in both North America and Europe nuclear cardiology is an important area of research and by implication also of clinical practice.

Great Britain seems to lag behind other countries in the adoption of nuclear cardiology, but little objective information is available. In 1983 a postal survey of consultant physicians in Scotland highlighted the poor availability of nuclear cardiology techniques.[2] Since this time, the position in other countries has altered considerably. To obtain information on current practice, we have analysed the results of a postal questionnaire sent on behalf of the British Nuclear Cardiology Group to departments of nuclear medicine and cardiology throughout Great Britain.

Methods

A questionnaire was sent to 143 hospitals known to perform nuclear medicine and the requested completion date was October 1988. The centres were identified from the membership lists of the British Nuclear Cardiology Group, the British Nuclear Medicine Society, the British Cardiac Society, and the Hospital Physicists Association, with cross referencing from the service lists of the major manufacturers of gamma cameras and nuclear medicine computers supplying the British market. While this is a small fraction of the hospitals in the country (total approximately 3000), it included all regional cardiac centres and most district hospitals providing a nuclear medicine service. Not every question was answered and the results are expressed as a percentage of the number of replies received.

Results

GENERAL RESPONSE AND STUDY NUMBERS

Sixty nine replies (48%) were received. Of these, 23 (33%) were teaching hospitals with a similar percentage of teaching hospitals in the non-responders (29 of 74 (39%)). The proportion of teaching and district hospitals was therefore representative of the survey group as a whole (χ^2 = 0·31, p = NS). The figure shows the geographical distribution of the respondents and non-respondents.

The respondents' definition of their departments was used. The largest proportion of replies was from departments of nuclear medicine (40%), followed by medical physics

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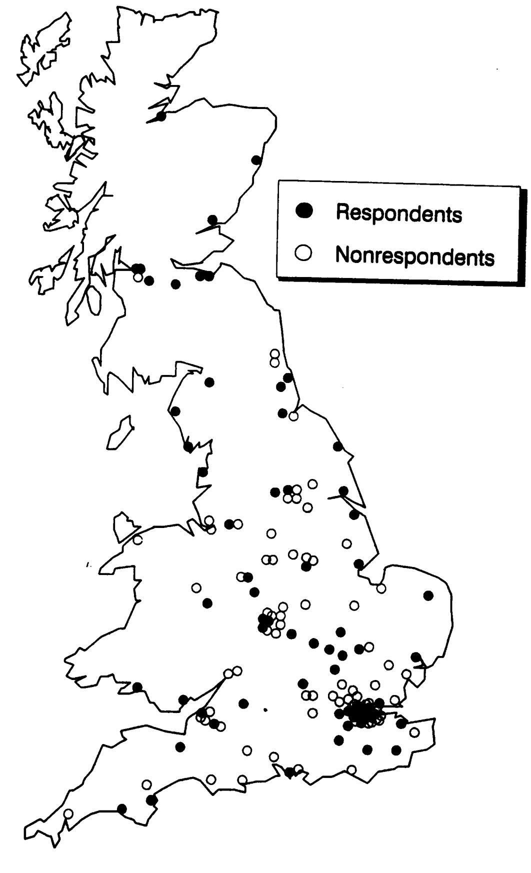

Map indicating the site of all centres that were circulated and whether a response was received to the questionnaire.

(26%), radiology (20%), and cardiology (11%). Departments of cardiology were more commonly represented among the teaching hospitals than the district general hospitals ($\chi^2 = 6{\cdot}8$, $p = 0{\cdot}009$), and departments of radiology or medical physics were more common among the district hospitals ($\chi^2 = 7{\cdot}2$, $p = 0{\cdot}007$). Research studies were performed in addition to routine clinical work in 78% of departments of cardiology, 65% of medical physics, 52% of nuclear medicine, and 22% of radiology. Research was significantly more common in teaching hospitals, being performed in 20 of the 21 teaching hospitals but only seven of the 28 district hospitals that replied ($\chi^2 = 23{\cdot}9$, $p = 1{\cdot}0 \times 10^{-6}$). Thus the repondents were polarised between research based departments of cardiology in teaching hospitals and clinically based departments of radiology or medical physics in the district hospitals.

Table 1 shows the number of studies reported. Fifty (74%) of 68 centres performed cardiac studies, and 11·7% of all nuclear medicine studies reported were cardiac. These numbers are similar to ones reported in a recent survey of general nuclear medicine departments,[3] where cardiac studies accounted for 11% of the workload. Teaching hospitals performed a significantly higher percentage of cardiac studies (16%) than district hospitals (7%) ($\chi^2 - 20{\cdot}7$, $p = 5{\cdot}4 \times 10^{-6}$), in keeping with the higher number of departments of cardiology represented in the teaching hospitals. Table 2 shows the distribution of types of cardiac study. Sixty four per cent of centres performed no first pass radionuclide ventriculography and 20% performed no thallium-201 scintigraphy. Thus in most centres equilibrium radionuclide ventriculography made up at least half of the workload with a variable proportion of thallium-201 scintigraphy.

Respondents were asked to assess trends in their workloads. About half the centres (53%) reported that their general imaging workload was increasing and slightly more (57%) that their cardiac workload was increasing. A comparison of trends with absolute workloads shows significant associations (table 3). For general nuclear mecicine, there was a significant tendency for small departments (up to 2000 studies per year) to report a rising trend ($\chi^2 = 4{\cdot}25$, $p < 0{\cdot}05$), but for cardiac investigations this situation was reversed. Smaller centres (up to 150 cardiac studies per year) were more likely to report a static or falling trend ($\chi^2 = 6{\cdot}57$, $p < 0{\cdot}02$).

The median proportion of patients studied as outpatients was 80%, confirming that nuclear cardiological investigations are usually outpatient procedures. Over 70% of centres reported that their most frequent referral source was a cardiologist. Of the 46 (67%) centres providing full data on referral pattern, 73% of all cardiac studies were requested by cardiologists, 16% by other physicians, and 11% by surgeons including cardiac surgeons.

EQUIPMENT AND STAFF

The mean number of cameras per centre was 1·8 (median 1, maximum 7). Mean camera age was 5·2 years (median 5, maximum 10). Teaching hospitals had almost twice as many cameras as district hospitals (mean 2·7 and 1·4 per centre), although camera age was similar (mean 5·2 and 5·2 years respectively). Each camera most commonly performed between 500 and 1500 studies per year. The percentage of centres according to camera load was <500 studies per camera = 5%, 501–1000 studies = 35%, 1001–1500 = 38%, 1501–2000 = 17%, >2001 studies per camera = 5%.

The staff groups who performed and interpreted studies varied widely (table 4) confirming the diversity of nuclear cardiological prac-

Table 1 Annual workload of imaging procedures (first pass radionuclide ventriculography, equilibrium radionuclide ventriculography, and thallium-201 myocardial perfusion imaging

Data	*All isotope studies*	*First pass rest*	*First pass stress*	*Equilibrium rest*	*Equilibrium stress*	*Thallium*
Number of replies	64	67	66	64	64	66
Percentage performing studies	95	28	3	72	41	64
Total studies	147 904	1474	1010	8080	2132	4602
Mean studies per centre	2425	78	505	176	82	110
Maximum number in any centre	8900	500	1000	1400	500	1500

Table 2 Number of hospitals according to the proportion of nuclear cardiology studies performed. Only 50 hospitals from which a reply to all three questions was received are included

Percentage	First pass RNV	Equilibrium RNV	Thallium-201
0	32	2	10
1–10	10	2	4
11–20	1	3	6
21–30	2	2	3
31–40	2	7	6
41–50	2	10	5
51–60	0	3	5
61–70	0	3	4
71–80	0	5	3
81–90	0	4	1
91–100	1	9	3

RNV, radionuclide ventriculography.

Table 3 Association between trends and annual workload

	Centres with rising case load	Centres with static or falling case load
Total studies:		
1–2000	21	11
>2000	10	16
Cardiac studies:		
1–150	12	17
>150	17	5

tice in Great Britain. In almost all centres, staff from several groups were involved at all stages. Rest studies were performed more commonly by radiographers or technicians (63%) than by doctors (20%), but doctors were more commonly involved in stress studies (48%). Radiologists reported the studies more commonly (28%) than they performed them (6%). In 64% of centres, reporting was performed by doctors only, in 34% it was by a group that included doctors, and in one centre reporting was performed by non-medical staff.

FIRST PASS RADIONUCLIDE VENTRICULOGRAPHY

First pass radionuclide ventriculography was the least common (14·4%) of the three major cardiological investigations. Of 18 centres performing such studies, two used a multicrystal gamma camera and the remainder a single crystal camera. The most common reason for performing the studies was to evaluate intracardiac shunting (47%), though it was also used to evaluate left (23%) and right (17%) ventricular ejection fractions.

EQUILIBRIUM RADIONUCLIDE VENTRICULOGRAPHY

Equilibrium radionuclide ventriculography was the commonest study performed, accounting for more than half (59%) of all cardiac studies. Some form of stress was used in 35 (61%) of the 57 centres that performed radionuclide ventriculography: of these, 66% used dynamic exercise, 9% isometric exercise, 20% cold pressor stress, and 5% pharmacological stress. Thirty four per cent of centres routinely withdrew cardiac medication before stress radionuclide ventriculography, 30% did not, and 34% gave a qualified answer, such as that it depended on the requesting physician.

Table 4 Number of centres according to the type of staff involved in cardiac procedures (more than one person may be involved)

	Rest study	Stress study	Reporting
Cardiologist	9	26	17
Nuclear physician	3	13	18
Radiologist	3	6	22
Physicist	13	12	20
Radiographer	19	10	1
Technician	28	26	2

In vivo erythrocyte labelling was the most common (76%) form of labelling, followed by semi in vitro (14%), human serum albumin (6%), and in vitro (4%). The commonest dose of technetium-99m was 740 MBq given in 31% of centres followed by 800 MBq in 19%. Nineteen per cent of centres gave doses of less than 500 MBq. All centres imaged in the left anterior oblique projection (or a modification) but, in addition, 51% imaged in the anterior projection, 28% in the right anterior oblique projection, and 11% in the left lateral projection. The commonest number of frames acquired per cardiac cycle was 16 (39%), 22% of centres acquired 20 frames, 17% acquired 24 frames, and 4% acquired 32 frames.

Nearly all centres analysed the studies to provide left ventricular ejection fraction (92%) and left ventricular wall motion (84%), but right ventricular ejection fraction (14%) and valve regurgitation (14%) were also sometimes measured. Fourier analysis was the commonest method of assessing wall motion (88%). For the calculation of background, the respondents showed preferences for a horseshoe shaped region of interest (63%), a single left ventricular region of interest rather than two regions (64%), and manual rather than automatic delineation of regions of interest (57%). Many centres thus prefer the manual methods of analysis to more complex automated methods.

One of the most striking findings of the study was the variation in the normal range for left ventricular ejection fraction. The lower limit had a median value of 50% (range 35–75%) and the upper limit a median of 100% (range 50–100%). Just over half (53%) of the respondents specified no upper limit. Four centres believe that the left ventricular ejection fraction should be at least 60% and three centres believe that this would represent abnormally increased function. The median lower limit of left ventricular ejection fraction was the same (50%) for centres using either one or two left ventricular regions of interest.

THALLIUM-201 MYOCARDIAL PERFUSION IMAGING

Thallium-201 scintigraphy represented 26·6% of all cardiac studies. Dynamic exercise was the commonest method of stress (62% of centres). Intravenous dipyridamole was used in 22% of centres, oral dipyridamole in 7%, and a combination of exercise and dipyridamole in 9%. Planar imaging was the most common technique (70%), followed by emission tomography (23%) and electrocardiogram gated imaging (7%). All centres performing tomography used rotating gamma cameras. Larger departments (more than 50 thallium studies per year) were more likely to use tomography than smaller departments

Table 5 Other cardiac studies

	Number of centres
Indium-111 white cells	9
Technetium-99m pyrophosphate	8
Technetium-99m isonitriles	7
Gallium-67 citrate	7
Non-imaging probe	6
Labelled fatty acids	2
Antimyosin antibody	2
Gold-195m	1
Meta-iodobenzylgluanidine (MIBG)	1

(χ^2 = 5·5, p = 0·02), and there was also a tendency that did not achieve statistical significance for teaching hospitals to be more likely to use tomography (χ^2 = 3·1, p = 0·077).

The commonest doses used were 80 MBq (33%) and 74 MBq (29%) and four centres (10%) used more than 80 MBq. The delay time between stress and redistribution images varied from two to five hours (median four), and no centre routinely imaged after five hours. A few respondents used quantitative analysis (43%) or washout analysis (26%), but quantitative analysis was more common in teaching hospitals than district hospitals (χ^2 = 3·0, p = 0·085).

OTHER STUDIES

Very few centres performed other forms of cardiac imaging (table 5). In most cases the number of such studies performed at any centre was low.

Discussion

The aim of this study was to obtain a representative view of the practice of nuclear cardiology in Great Britain. While such a study is unlikely to be complete, we believe that we have achieved our aim. We estimate that about 200 hospitals in Great Britain have at least one gamma camera. Thus we requested information from 70% of centres performing nuclear medicine and, although the response rate was relatively low, there was no bias towards either teaching hospitals or district general hospitals in the responders compared with the non-responders. The geographical distribution of the two groups was similar.

By extrapolation from the 48% response rate, we estimate that the annual rate of nuclear medicine procedures reported was approximately 6000 per million population per year. The rate of nuclear cardiological investigation was 700 per million per year. In the United States in 1985, the rates for general nuclear medicine and nuclear cardiology were 29 600[4] and 3550 per million per year[4] respectively. In 1988 this last figure had increased to 4000 per million per year.[5] Thus five times as many procedures are performed in the United States as in Great Britain, though the proportion of nuclear cardiology to general nuclear medicine is similar. This survey cannot indicate the reason for this difference, but it does allow some informed guesses to be made.

The number of hospitals with suitable equipment is clearly an important factor. In the United States in 1983 it was estimated that approximately half of the hospitals had nuclear medicine facilities[6] whereas the proportion in Great Britain is approximately one third, even in 1990. Median camera age in Great Britain is five years with some centres having 10 year old cameras. Given the rapid advances in camera and computer design this equipment is relatively old, suggesting a low level of capital investment. One effect of the shortage of modern cameras is the low percentage (23%) of centres performing thallium-201 emission tomographic imaging. Although the debate about the relative accuracies of planar and tomographic thallium-201 imaging continues, the tide has turned in favour of tomography. A potent factor in persuading clinical cardiologists to use myocardial perfusion imaging is their familiarity with the images and the ease of interpretation. Tomographic imaging, if well performed is better than planar imaging in these respects and its scarcity may be one reason for the low use of myocardial perfusion imaging.

A second point highlighted by the survey that may explain the difference in nuclear cardiology practice between Great Britain and the United States is the diversity of staff that perform studies. Little formal medical training in nuclear medicine is available in Great Britain. There are eight full-time registrars in nuclear medicine, eight senior registrars, 29 consultants, and six senior lecturers or professors. Most departments are not run, therefore, by full-time nuclear medicine physicians and a very wide range of skills are used. Technicians and radiographers most commonly perform rest studies and cardiologists most commonly perform stress studies. In contrast, radiologists least commonly perform rest or stress studies but most commonly report them. The relatively large number of centres in which cardiologists perform stress studies is encouraging but the fact that they are less commonly involved in reporting is disappointing because the report is most likely to be clinically relevant if formed in close collaboration with the referring clinician. Many cardiologists hold regular meetings where the results of their patients' investigations are reviewed with the relevant clinical staff. Such a setting would be ideal for the reporting of nuclear cardiological procedures.

Apart from differences in the availability and practice of nuclear cardiology, other factors will clearly influence the relative rates of investigation in Great Britain and the United States. These include a more aggressive style of investigation and treatment in the United States, a greater awareness of potential litigation, and different mechanisms of financing medical care. For these reasons, the comparison between countries should not be taken too far.

In addition to the low use of nuclear cardiology, we have identified large discrepancies in practice throughout Great Britain. A particularly worrying finding is the disparity in normal ranges for left ventricular ejection fraction, with the lower range of normal varying from 35% to 75%. It is not known whether this is the result of different perceptions of normality, differences in analytical technique, or technical errors. Clearly, it is important that values are transferrable between centres and this finding should serve as a spur to the standardisation of methods of acquisition and analysis. One of the most potent sources of variation is the estimation of background counts. The commonest method was to use a manually defined horseshoe region of interest lateral and inferior to the left ventricle with a single left ventricular region of interest. This method seems to be the most reproducible, but a greater degree of standardisation is required. It is also surprising to find that most centres use projections in addition to the one that best separates the left and right ventricles in equilibrium radionuclide ventriculography. Acquisition in only a single projection gives a distorted view of the left ventricle with weighting towards the anterior part of the blood pool because of attenuation of counts from the more distant inferior portion.[7] In an attempt to overcome the problem, 79% of centres also image in the anterior or right anterior oblique projections. The reliability of these projections is questionable because of the overlying right ventricle, and the left lateral or left posterior oblique projections are preferable.

For the analysis of wall motion 67% of centres used Fourier phase and amplitude imaging rather than alternative methods such as those based in the motion of contours. This is encouraging because objective measurements of phase and amplitude should aid standardisation. The assessment of contours is not ideal because of its subjectivity and the fact that only the motion of walls seen end-on can be assessed from a contour display.

It is particularly disappointing that 29% of centres used either isometric stress or cold pressor stress to assess left ventricular function during stress. Neither of these techniques is adequate to provoke abnormalities in patients with coronary artery disease though new wall motion abnormalities are highly specific.[8-10]

There was understandably less variation in technique for thallium-201 scintrigraphy but the major finding was that only one quarter of centres used emission tomographic imaging. The strengths and usefulness of emission tomography have already been discussed. There was a significant tendency for larger centres to perform tomography. While it is tempting to speculate that the better quality of tomograms prompts more referrals, an alternative explanation is that only the larger centres have suitable equipment.

Although there was general agreement on the dose of thallium-201, four centres routinely use a dose higher than that recommended by the Administration of Radioactive Substances Advisory Committee (80 MBq). There is increasing pressure to use higher doses in order to obtain good quality tomograms and to allow redistribution imaging at later times. No centres reported redistribution imaging later than five hours after the injection of the isotope, but since the date of the survey evidence has emerged that imaging at four hours can underestimate the extent of viable myocardium.[11] Perhaps it would be better to repeat imaging after a further injection of thallium-201 at rest rather than to study late redistribution. This of course increases the radiation burden to the patient, but doses of 120 to 160 MBq are becoming accepted practice in the United States.[12] The large effective dose equivalents (37·5 to 50 mSv) must be weighed against the potential benefits.

In conclusion, we found that nuclear cardiology investigation is less often used in Great Britain than would be expected by extrapolation from data on some other countries. We have highlighted some practical aspects that may explain the discrepancy, and we believe that the position is unlikely to change without an increase in the number of cardiologists and physicians with experience in nuclear cardiology. This is most likely to come about through undergraduate and postgraduate education and we agree with proposals for a new training programme for cardiology including the statement that "trainees must now acquire not only clinical skills but also considerable expertise in ... nuclear cardiology."[13]

We are grateful to all respondents who completed the questionnaire. We apologise to any centres that would have been eligible but did not receive a questionnaire. We are anxious to hear from them so that future surveys may be more complete.

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