CT SCANNING IN AUSTRALIA

a report by the

NATIONAL

HEALTH

TECHNOLOGY

ADVISORY

PANEL

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A REPORT BY THE

NATIONAL HEALTH TECHNOLOGY ADVISORY PANEL

Any comments or information relevant to the subject matter of this report would be welcome. Correspondence should be directed to:

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AUSTRALIAN INSTITUTE OF HEALTH

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CT SCANNING IN AUSTRALIA

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EXECUTIVE SUMMARY

- This report is intended to provide an overview of trends in the usage of CT scanning in Australia, and to draw attention to the areas of benefit and uncertainty associated with this technology.

Numbers of CT Scanners and Services

- By mid 1987 there were at least 170 CT units in Australia, 118 in the private sector and 52 in the public sector. Geographically there is some imbalance in their distribution, with some country regions lacking services.

- In 1986/87 Medicare payments for CT services totalled nearly $68 million. Taking into account public hospital costs and individual contributions, the total cost to Australia of CT services was in the region of $90 million.

- There has been very rapid growth in CT services since 1980/81.

  - In 1986/87 medical benefits were paid for over 279,000 CT examinations, 7 times the number in 1980/81. These included examinations on patients referred from public hospitals to private practice.

  - Preliminary Medicare data for the first half of 1987/88 suggest that growth in private sector CT services slowed during that period.

- CT has replaced a number of procedures which are less effective or more invasive, but the increase in the number of CT examinations since 1980/81 far exceeds any decline in the number of alternative non-surgical diagnostic procedures. Use of CT has also resulted in a reduction in exploratory surgery. The extent of this reduction is not known.

Safety and Efficacy of CT

- A large body of evidence exists for the efficacy and cost effectiveness of CT when appropriately applied.

- It would be inappropriate to use CT

  - to rule out disease in cases where it is generally accepted that an adequate clinical examination would suffice;

  - solely to insure against possible legal action;

  - to provide information which could have no effect on patient management.

- There are small but real risks associated with CT examinations, related to the use of contrast media and ionising radiation. These need to be taken into account when CT examinations are proposed.

Place of CT in Australian Health Care

- There are several reasons for the rapid growth in CT examinations, including demonstrated diagnostic excellence, value in patient management, reimbursement policies, a broad referral basis, and policies on public sector CT procurement. The Panel notes the impact of different funding mechanisms on the distribution of this technology and access to it.

- CT will continue to be a major diagnostic modality in Australia for the foreseeable future. The Panel considers that competing technologies will have little effect on the numbers of CT services over the next 5 years.

- Lower cost CT scanners are now available. These have lower technical capability than the more expensive machines, but may be able to provide effective diagnostic coverage in many situations. Their role in health care services merits careful consideration by government and professional bodies.

- Little quantitative information is available on how CT is used in Australia or its effect on patient management.

- The Panel <u>recommends</u> that:

  - In view of the high cost to Australia of this modality a study be undertaken to determine its contribution to patient care and the extent of cost savings achieved through its use. This would require the collection of detailed, quantitative information from a sample of CT units on the indications for which patients are referred, sources of referral, the results of examinations, and their contribution to diagnosis and management decisions.

  - Professional bodies, including the Royal Australasian College of Radiologists, the Royal Australasian College of Physicians, the Royal Australasian College of Surgeons and the Royal Australian College of General Practitioners, consider the development of guidelines for referring medical practitioners on the use of CT. Such guidelines should include advice on appropriate indications for CT examination, risks, costs and expected benefits.

- The Panel would also support publication of data on CT from Australian sources as an aid to education of users of the technology.

INTRODUCTION

In this report, the NHTAP has sought to identify trends in the usage and distribution of CT services in Australia, to reflect where possible, changes in clinical practice that have resulted from the use of CT, and to indicate the overall effect of the technology on the health care system.

The development of CT scanning in the early 1970s represented a dramatic advance in diagnostic imaging technology, giving clinicians rapid access to more detailed information. The technology was introduced into Australia in 1975, and diffused rapidly, as it did in a number of other countries. Two major factors influencing the spread of CT were its obvious benefits, as recognised by radiologists and clinicians, and the rate of innovation in scanner design, which resulted in rapid improvement in performance and widening of applications.

In Australia, as elsewhere, concerns emerged that relatively uncontrolled introduction of this expensive technology had occurred before there had been a detailed appraisal of its costs and appropriate clinical role. While CT is now generally regarded as an essential component of diagnostic imaging services, even at this stage it continues to give rise to concerns on the part of governments and health administrators as to its costs, distribution, types of patients examined and applications. Further questions on its appropriate place in health care have begun to emerge with the development of competing modalities, including magnetic resonance imaging (MRI).

The Panel considered that it would be useful to review CT services in Australia, and to provide information on the clinical applications and cost of the technology. This report also seeks to identify areas where further information is desirable. Such an overview will inevitably have a different perspective from that of users of the technology who will be aware of its benefits to individual patients.

DESCRIPTION OF CT AND ITS DEVELOPMENT

Computed tomography (CT) was developed in the UK and first used in the early 1970s. The technology combines X-ray equipment with a computer and a cathode ray tube display to produce cross-sectional images of the body. The patient is positioned within a gantry containing an X-ray source and up to 2000 detectors. The source and detectors are opposite one another and during scanning are rotated in a synchronised fashion so that the detectors measure the radiation absorbed along many different paths through the cross section being imaged. Several hundred thousand absorption measurements are made. Signals from the detectors are digitised and the data stored and processed by computer. Manipulation of the data by the computer gives a set of numbers, each representing the absorption value of a tiny volume element within the anatomic cross-section. A shade of grey depending on the absorption value is assigned to each, and these pixels are assembled to construct the image.

The first generation of CT machines were head scanners, initially developed in the UK by EMI, with the first commercial scanner being installed at the Mayo Clinic in 1973. A single X-ray source and detector were used, and absorption measurements were made while the source and detector were moved about the patient in a series of transverse motions and rotations. Five minutes were required to scan a single slice, a time that was acceptable for brain scanning only because the brain is not subject to involuntary motion. Faster scanning is required for body scanners to avoid motion artifacts.

A second generation of scanners was introduced early in 1975. The new technology incorporated multiple detectors (about 30) with a single X-ray fan beam. It continued to use a combination of transverse and rotational motion during measurements. Scan times were now reduced to 20 seconds, and the technology could be applied to body scanning.

In the third generation of scanners, introduced late in 1975, the X-ray fan angle was widened to cover the whole body cross-section and a much larger number of detectors was used (300-500). The transverse motion was eliminated and scan times were reduced to 5 seconds.

Although most modern machines are basically similar to the third generation scanners, subsequent development of the technology has produced further reductions in scan times, image reconstruction time and slice thickness, with improved spatial resolution. More recent scanners have scan times as low as 1.5 seconds and image reconstruction times of 20 seconds or less. Minimum slice thickness has decreased to around 1.4 mm and spatial resolution to the order of 0.5 mm.

This improvement in performance has been achieved through use of many hundreds of detectors in the scanner, development of more stable detectors and improved calibration procedures, developments in computer design and software and use of higher doses of radiation. These improvements have been accompanied in some models by increases in costs, a top of the range scanner now approaching $M1.5 in Australia. A relatively recent development has been the availability of lower cost scanners (of the order of $M0.5) which are capable of producing adequate images for many applications.

In Australia, as in other countries, older types of CT continued in use as the newer generation machines became available. It is understood that some EMI head scanners were until recently operational in this country.

Radiologically opaque materials known as contrast media are frequently used to enhance radiographic contrast during CT scanning. They are usually introduced intravenously and, because of their high X-ray absorption, provide enhanced visualisation of vascular structures with better detection of pathology such as tumours. The contrast media used have most commonly been ionic tri-iodinated benzoic acid derivatives such as ditriazoate, which have been the mainstay of contrast radiological studies since the 1960s. However there is growing use of newer low osmolality derivatives which are considered to be safer and cause less discomfort to the patient, but which are much more expensive.

For contrast studies of the spinal canal, the contrast medium is injected intrathecally, The contrast medium used is one of the metrizamide family of compounds, non-ionic iodinated benzene derivatives which were introduced in the early 1970s.

PATTERNS OF USAGE OF CT IN AUSTRALIA

Number of CT Services

Figure 1 compares two sets of data:

* The numbers of privately performed CT services in Australia over the period 1980-81 to 1986-87 (extracted from data on all services for which medical benefits have been paid)

* CT examinations performed in public hospitals over the period 1980-81 to 1985-86. (These figures include examinations of private patients in public hospitals, so that the two sets of data overlap to some extent and are not additive.)

The Panel is aware that many privately performed CT services result from the referral to private practices of patients from public hospitals which either lack CT services or have overloaded facilities. Such referral patterns should be borne in mind when considering data in Figures 1 and 2 and Table 2-4.

The data show that there has been rapid growth in both the public and private sectors. In 1986-87, medical benefits were paid for over 279,000 CT services, seven times the figure in 1980-81. In 1985-86, there were over 90,000 CT examinations in public hospitals, three times the figure in 1980-81. Since there has been a substantial increase in the number of CT scanners in public hospitals since 1985/86, the Panel believes that the number of CT scans performed annually in public hospitals would now be considerably higher.

Figure 2 shows that in recent years the rate of increase in the number of privately performed CT examinations has been much higher than the growth rate for all services recorded in the medical benefits data, which increased by 58% from 1980/81 to 1986/87.

The growth in CT usage is compared with the increase in the medical benefits data for some other diagnostic services in Table 1:

TABLE 1 : GROWTH IN SOME SERVICES FOR WHICH MEDICAL BENEFITS WERE PAID, 1980/81 TO 1986/87

SERVICE	PERCENTAGE INCREASE	
CT examinations	605%	
All other radiology services	73%	
All endoscopy	77%	(to 1985/86)
All pathology services	91%	
Cerebral angiography	440%	
Ultrasound	360%	

Source : Commonwealth Department of Community Services and Health

Preliminary Medicare Benefits data for 1987/88 give a total of 144,266 privately performed CT services for the first half of the year, suggesting that the full year figure may be around 289,000. The figures indicate that the growth in the incidence of private CT services may have slowed significantly during that period.

Figure 3 compares the types of scans and scanners used, for privately performed CT examinations, in 1980-81 and 1985-86. In 1980-81, the great majority of CT examinations were of the brain, although most were performed on body scanners. Over the period the number of body scans increased substantially, from 21% to 48% of all examinations. The percentage of services using brain scanners fell from 17% in 1980-81 to less than 1% in 1985-86.

In 1985/86, as in 1980/81, most scans for which medical benefits were paid involved the use of a contrast medium. However, while the percentage of brain scans using contrast medium remained at about 84%, the percentage of body scans with contrast fell from 66% to 48%. It has been suggested to the Panel that the fall in the percentage of body scans using contrast may be due to an increase in the number of spinal scans, which usually do not require contrast (Sorby, personal communication).

The public hospital data for the most part do not distinguish between plain and contrast studies. The data from those hospitals which have separated these studies indicate considerable variation in their proportions. In most cases, the percentages of contrast studies appear to be well below the corresponding level from the medical benefits data. The Royal Australasian College of Radiologists (RACR) has suggested that this difference is associated with the number of scans performed in hospitals on patients with head trauma and acute stroke, where contrast enhancement is not required in the evaluation of intracranial haemorrhage.

The data discussed in this section are given in detail in Tables 7-12 in Appendix I.

Fig 1: GROWTH IN CT SERVICES

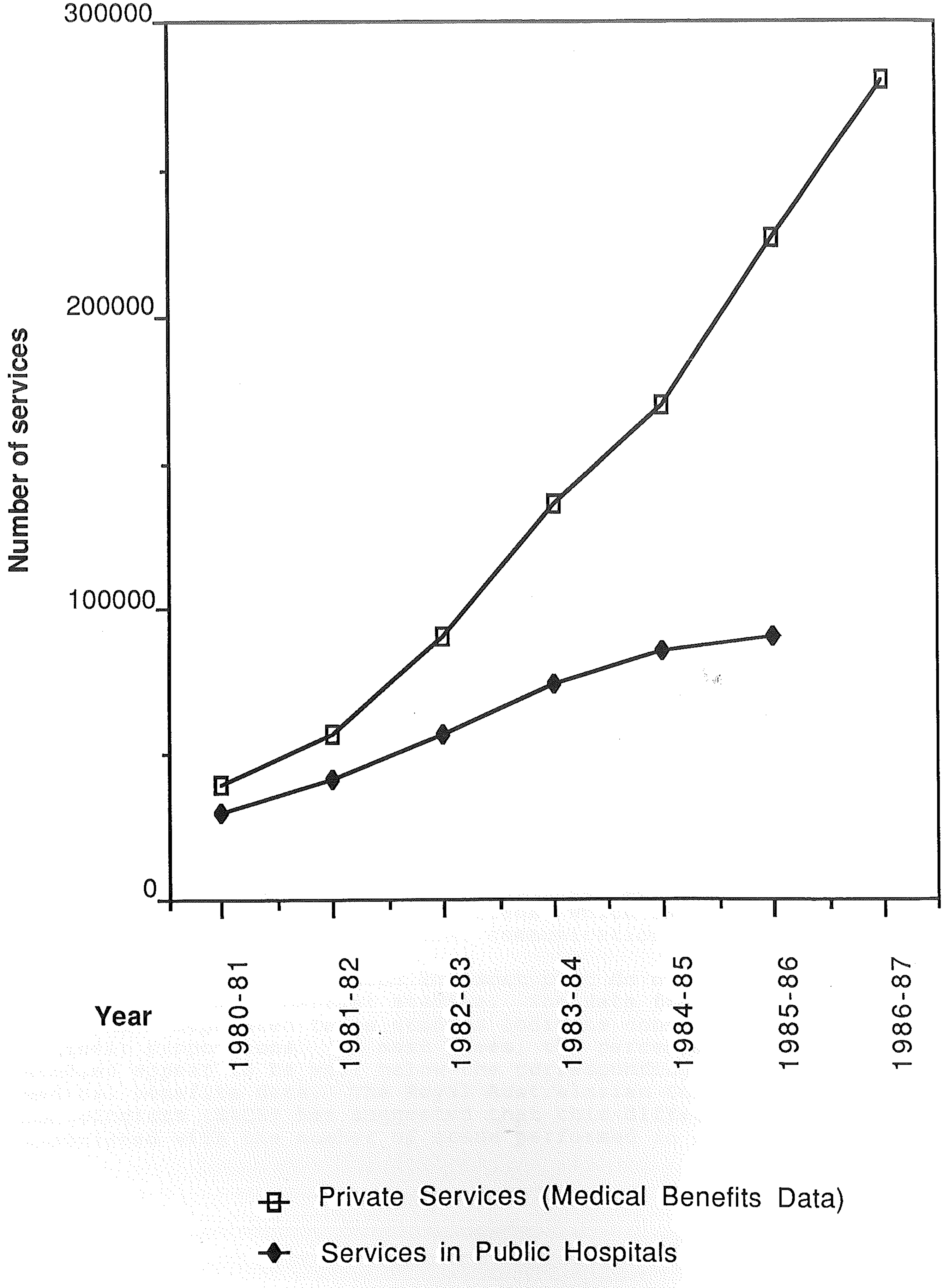


Fig 2: NUMBER OF CT SERVICES AS A PERCENTAGE OF ALL MEDICAL BENEFITS SERVICES

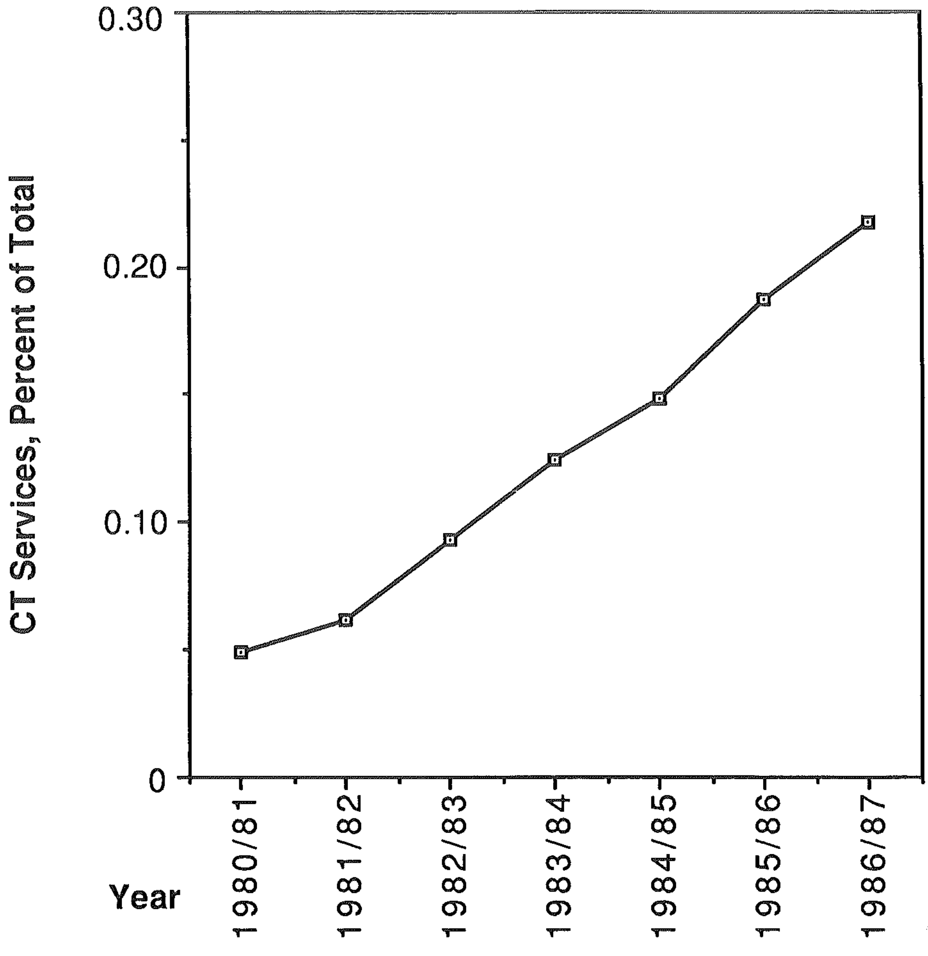
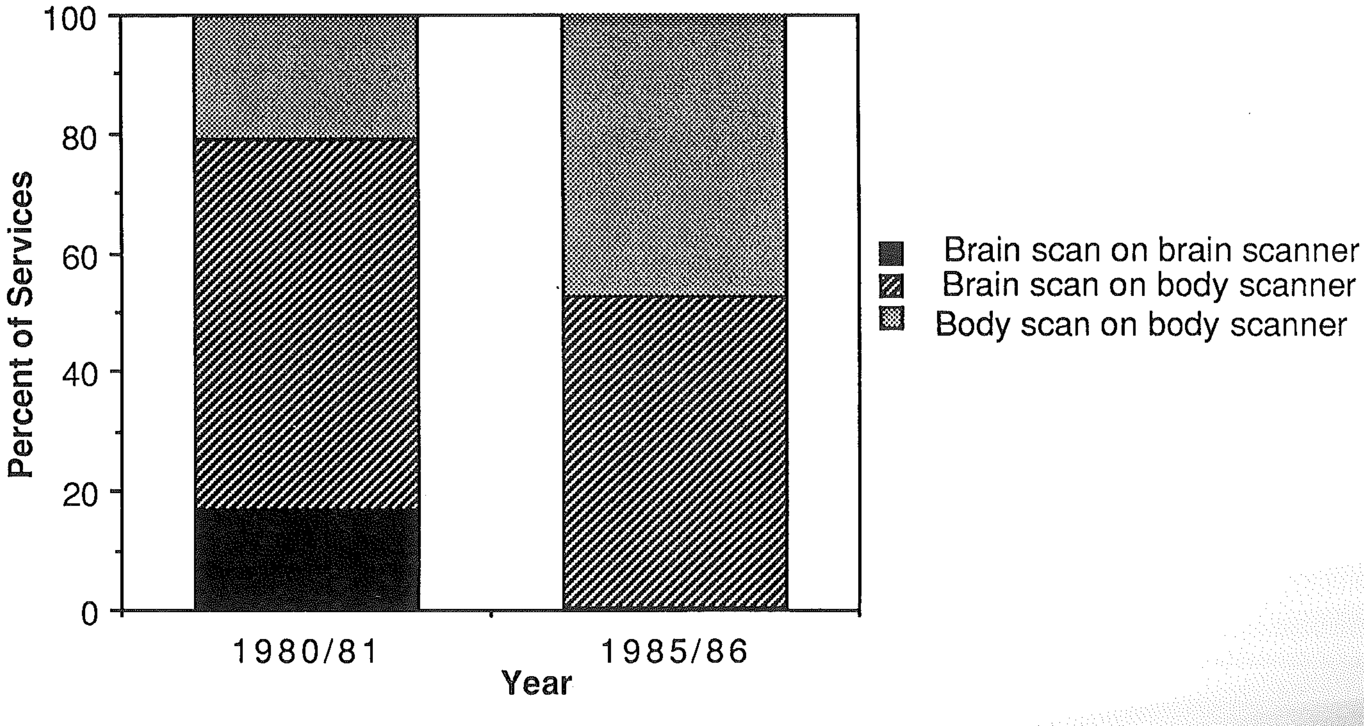


Fig 3: TYPES OF SCANS AND SCANNERS (MEDICAL BENEFITS DATA)



Number of CT Units

Information on the numbers, distribution and installation dates of CT units in Australia has been obtained from surveys undertaken by the then Commonwealth Department of Health and by NHTAP in 1986. There has been some subsequent updating, but records of installation after September 1986 are believed to be incomplete, particularly for the private sector.

The data indicate that there are at least 170 CT units in Australia, 52 in the public sector and 118 in the private sector. Table 2 gives estimates of the number of units by State and by sector. There is considerable variation among the States in the distribution between sectors.

Table 2 also gives the number of units per million population of each State and Australia as a whole. New South Wales, Queensland and the Northern Territory are above the national figure of 10.8 units per million, while the other States are below. The ACT has the lowest figure, with 7.7 units per million.

TABLE 2 NUMBER OF CT UNITS IN AUSTRALIA IN MID 1987

	PUBLIC	PRIVATE	TOTAL	NUMBER/MILLION POPULATION
NSW	11	53	64	11.6
VIC	20	21	41	9.9
QLD	8	22	30	11.6
SA	5	9	14	10.2
WA	5	8	13	9.2
TAS	1	3	4	9.0
NT	1	1	2	13.3
ACT	1	1	2	7.7
AUSTRALIA	52	118	170	10.8

Sources : Commonwealth Department of Community Services and Health, NHTAP Secretariat

The geographical distribution of CT scanners in Australia is shown in Table 3. The figures suggest some imbalance in distribution, with an excessive concentration of CT units in some regions and inadequate services in others. For example, in Queensland there are four CT scanners on the Gold Coast, approximately one for every 33,000 inhabitants (compared to approximate ratios of one in 77,000 for Brisbane and one in 72,000 for Sydney). However, the Wide Bay - Burnett region, with a total population close to 170,000, lacked CT services at the time of the survey. In NSW, the south-east regions are poorly supplied with CT services compared to the north-east, and the survey indicated an absence of services in the Bathurst - Orange region. (Subsequent advice to the Panel is that there is now a private unit in this region.) The remote inland of Australia is lacking in CT services, reflecting its small, widely dispersed population.

Table 4 gives the distribution of public and private scanners between capital cities and country regions. In NSW, Queensland and Tasmania, CT services outside the capital cities are provided primarily by the private sector, while in Victoria the public sector provides a higher proportion of regional CT services. These distribution data may give some indication of areas where there has been significant referral of public hospital patients to private sector facilities.

To give an indication of growth rates, numbers of CT units are plotted against installation dates to September 1986, for the public and private sectors, in Figure 4. Each data point refers to the cumulative total of scanners installed in earlier years to the year in question. Twelve units whose installation dates were not available are not included; for nine of these, information on the CT models suggests installation dates between 1983 and 1986. In addition there are likely to be a number of disused earlier CT units which are not included in the records. Figures given by Banta (1) indicate that there were 23 scanners in Australia in 1979.

Even with these limitations, the data demonstrate the rapid growth in the number of installations, particularly in the private sector. This trend reflects government policies which constrained spending in public hospitals, encouraging referral to private facilities, and reimbursement policies favoring private sector growth. Earlier government approaches to the introduction of CT and other new health technologies have been discussed by Sax (2).

TABLE 3 : GEOGRAPHIC DISTRIBUTION OF CT SCANNERS

LOCATION	NUMBER OF SCANNERS	LOCATION	NUMBER OF SCANNERS
NSW		**QLD**	
Sydney	43	Brisbane	15
Newcastle	3	Gold Coast	4
Tweed Heads	2	Toowoomba	3
Lismore	1	Buderim	1
Inverell	1	Rockhampton	1
Tamworth	1	Mackay	1
Coffs Harbour	2	Townsville	3
Pt Macquarie	1	Cairns	2
Taree	1		
Maitland	1		
Gosford	2	**SA**	
Cardiff	1		
Wollongong	1	Adelaide	13
Dubbo	1	Whyalla	1
Wagga	1		
Albury	1		
Bathurst	1		
		WA	
VIC		Perth	12
		Geraldton	1
Melbourne	31		
Ballarat	2		
Bendigo	1	**TAS**	
Geelong	2		
Shepparton	1	Hobart	2
Mildura	1	Launceston	1
Warrnambool	1	Devonport	1
Sale	1		
Traralgon	1		
		ACT	
		Canberra	2
		NT	
		Darwin	2

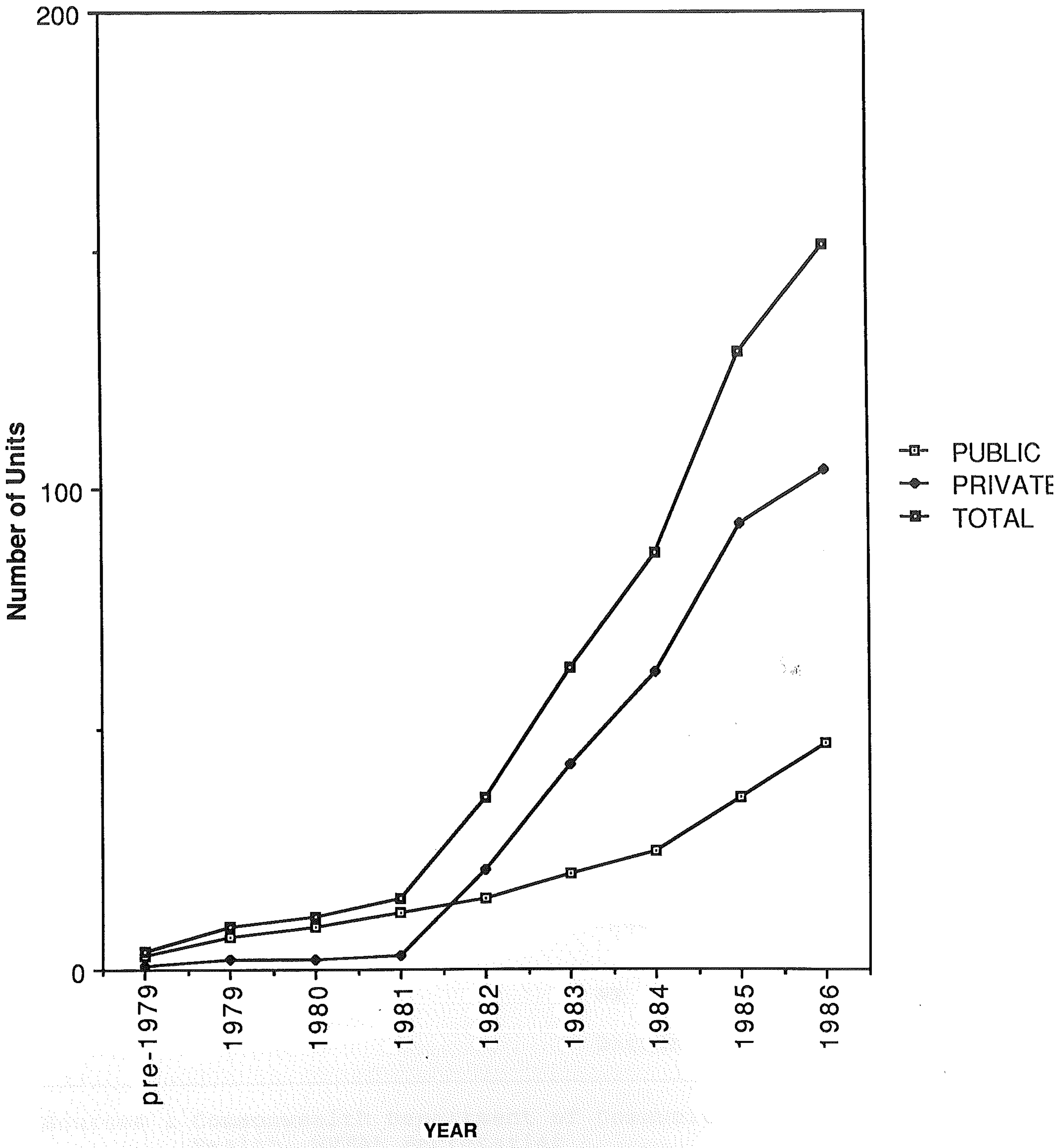
Sources : Commonwealth Department of Community Services and Health, NHTAP Secretariat

TABLE 4 : DISTRIBUTION OF PUBLIC AND PRIVATE SCANNERS BETWEEN CAPITAL CITIES AND COUNTRY REGIONS

STATE/TERRITORY	CAPITAL CITIES		REGIONAL	
	PUBLIC	PRIVATE	PUBLIC	PRIVATE
NSW	9	34	2	19
Vic	13	18	7	3
Qld	6	9	2	13
SA	5	8		1
WA	5	7		1
Tas	1	1		2
ACT	1	1		
NT	1	1		

Sources : Commonwealth Department of Community Services and Health, NHTAP Secretariat

Fig 4: NUMBERS OF CT UNITS BY INSTALLATION DATE



COMPARISON WITH OVERSEAS DATA

It is of interest to compare Australian data for numbers of CT scanners per million population with overseas data. The Australian figure of 10.8 scanners per million population (8.6 per million in 1985) is higher than the figures reported for a number of European countries. In 1985 West Germany had 7.3 CT scanners per million population, Switzerland 6.2, Sweden 5.6, Austria 4.0, the Netherlands 3.1, France 2.8 and the UK 2.3 (3). The Royal College of Radiologists has recommended that there should be one machine for every 250,000 population (4 per million) within the United Kingdom (4).

However, in Japan in October 1985 there were 3513 CT units or 29.2 per million population (Kimura,, personal communication). In the USA there were 1471 units in 1980 (5) and approximately 3,500 (14.7 per million) in 1985 (3).

The RACR (6) has noted that few nations have set fixed guidelines for the supply of CT scanners, and that any such guidelines would quickly become out of date. The Panel agrees that formulation and application of guidelines or regulations setting the number of scanners in Australia would be of limited use or relevance. The comparison with overseas data is interesting but it appears difficult to use the experience of other countries in developing a realistic policy on numbers and distribution of CT scanners in Australia. Numbers of CT scanners in each country reflect the different health care systems and the variation in referral patterns, availability of other methods, approach to diagnosis and management, medicolegal pressures, and patient demand and reimbursement mechanisms. The presence of domestic production of CT scanners could also have influenced the number deployed in certain countries.

While the value of CT is well established in the diagnosis and management of a number of conditions, there appears to be insufficient data, either in Australia or other countries, to convincingly support any given number of CT scanners on the basis of demonstrated overall gains in population health status.

A more useful approach for Australia might be to obtain estimates of projected numbers of CT services required for conditions where use of the technology is considered essential, taking into account population distribution, geographic factors, availability of regional specialty centres and departments of radiology.

CLINICAL ROLE OF CT

The clinical role of CT has developed from its capacity to provide information in three dimensions, (through sequential slices), its power to discriminate soft tissue, its capacity for simultaneous imaging of multiple organ systems, and its high resolution (Jones, RACR, personal communication).

As a result of these characteristics, CT can provide high resolution images, not previously available, of:

* solid organs such as the brain, liver, spleen, pancreas and kidneys;
* the larynx, pharynx and soft tissues of the neck;
* the mediastinum, retroperitoneum and peritoneal cavity;
* soft tissues of the trunk and limbs;
* complex structures such as the skull base and vertebral column;
* small structures such the pituitary gland, middle and inner ears, adrenal glands and the biliary tree.

The imaging capacity of CT is used in three major types of application:

* to give information which can aid in diagnosis;
* in disease management, for example in the staging of cancer;
* in the guidance of therapeutic or interventional procedures, particularly radiotherapy, biopsy and abscess drainage.

In many applications CT has replaced higher risk and painful invasive procedures. It has frequently improved accuracy, and in some cases has provided information which was not previously available. The detailed information provided by CT permits greater precision in surgery as well as avoidance of inappropriate operations, reducing risk and morbidity for the patient (Pegg, personal communication). For a number of conditions (such as subdural haematoma and brain tumours), CT scanning allows earlier diagnosis and institution of treatment, which may result in more rapid and complete recovery. CT scanning also facilitates undergraduate and postgraduate teaching (Burns, personal communication).

A number of studies have provided evidence of the efficacy and cost-effectiveness of CT when appropriately applied (7). For example, a study on the application of body CT, covering 2619 hospital patients, showed that overall, 53% of scans produced a unique or substantial contribution to diagnostic understanding, and 15% contributed to a change in treatment. It also showed that CT reduced surgery by 14% and angiography by 11%. However, the value of CT varied considerably from case to case, depending on the condition or anatomic region being investigated (8).

Detailed information on specific applications of CT is given in Appendix II. In many applications, the benefits of CT are clear and well established. Among these applications are:

* diagnosis of intracranial injury in head trauma with a significant probability of such injury;

* diagnosis or exclusion of internal abdominal injury where there is a significant probability of its presence, in abdominal trauma patients;

* diagnosis of intracranial tumours;

* primary diagnosis of some cancers of the body such as renal and adrenal tumours;

* staging of cancer particularly in the brain, lung, mediastinum, oesophagus, bladder, pancreas, head and neck, kidney and testicles;

* diagnosis of lumbar and cervical spinal disc herniations (although CT may not replace myelography in all cases)

* guidance of biopsies of tumours, and localisation and drainage of fluid collections such as abscesses, where less costly techniques such as fluoroscopy or ultrasound are inadequate;

* measuring response of some tumours to treatment

* radiotherapy planning.

The value of CT is less certain in studies of stroke patients, and in examinations of accident cases with only minor injuries.

It would be inappropriate to use CT:

* to rule out disease in cases where it is generally accepted that an adequate clinical examination would suffice;

* solely as a means of insuring against possible legal action;

* to provide information which could have no effect on patient management.

TRENDS IN THE INCIDENCE OF PROCEDURES REPLACED BY CT

Table 5 shows the change in the incidence of non-surgical diagnostic procedures affected by the introduction of CT, from 1977-78 to 1986-87, at a major teaching hospital where CT was introduced in 1978-79. Detailed data are given in Table 13, Appendix I. The data indicate an association between the introduction of CT and a sharp decline in the use of pneumoencephalography, isotopic brain scans, cerebral angiography, and lymphograms. They also indicate a reduction in the use of myelography and skull X-rays.

TABLE 5
CHANGE IN INCIDENCE OF NON-SURGICAL DIAGNOSTIC PROCEDURES AFFECTED BY CT, AT A TEACHING HOSPITAL 1977/78 TO 1986/87

PROCEDURE	1977/78	INCIDENCE 1980/81	1986/87
Total X-ray examinations	83,920	86,890	93,994
Skull X-rays	3,156	2,585	2,917
Radioisotope brain scans	2,437	366	6
Electroencephalograms	1,643	1,597	1,384
Neuroangiograms	1,456	486	885
Pneumoencephalograms	40	-	-
Myelograms	371	308	305
Abdominal arteriograms	145	151	372
Lymphangiograms	110	27	-
CT Head	-	2,522	2,229
CT Body	-	1,731	2,029

Sources : W A Sorby, personal communication, RACR Statement on CT Scanning, 1984)

At the same hospital, 200 interventional procedures guided by CT are performed each year. All these cases would have required surgery if CT were not available (Sorby, personal communication).

Figure 5 compares changes in the incidence in the medical benefits data of most of the non-surgical diagnostic procedures identified above, over the period 1980-81 to 1985-86. The numbers of these procedures compared with the number of CT scans are given in Table 14, Appendix I. Growth in the use of CT in the private sector over this period appears to have been associated with a decline in claims for myelography, pneumoencephalography, lymphography and isotopic brain scans, while the number of skull X-rays appears to be unaffected.

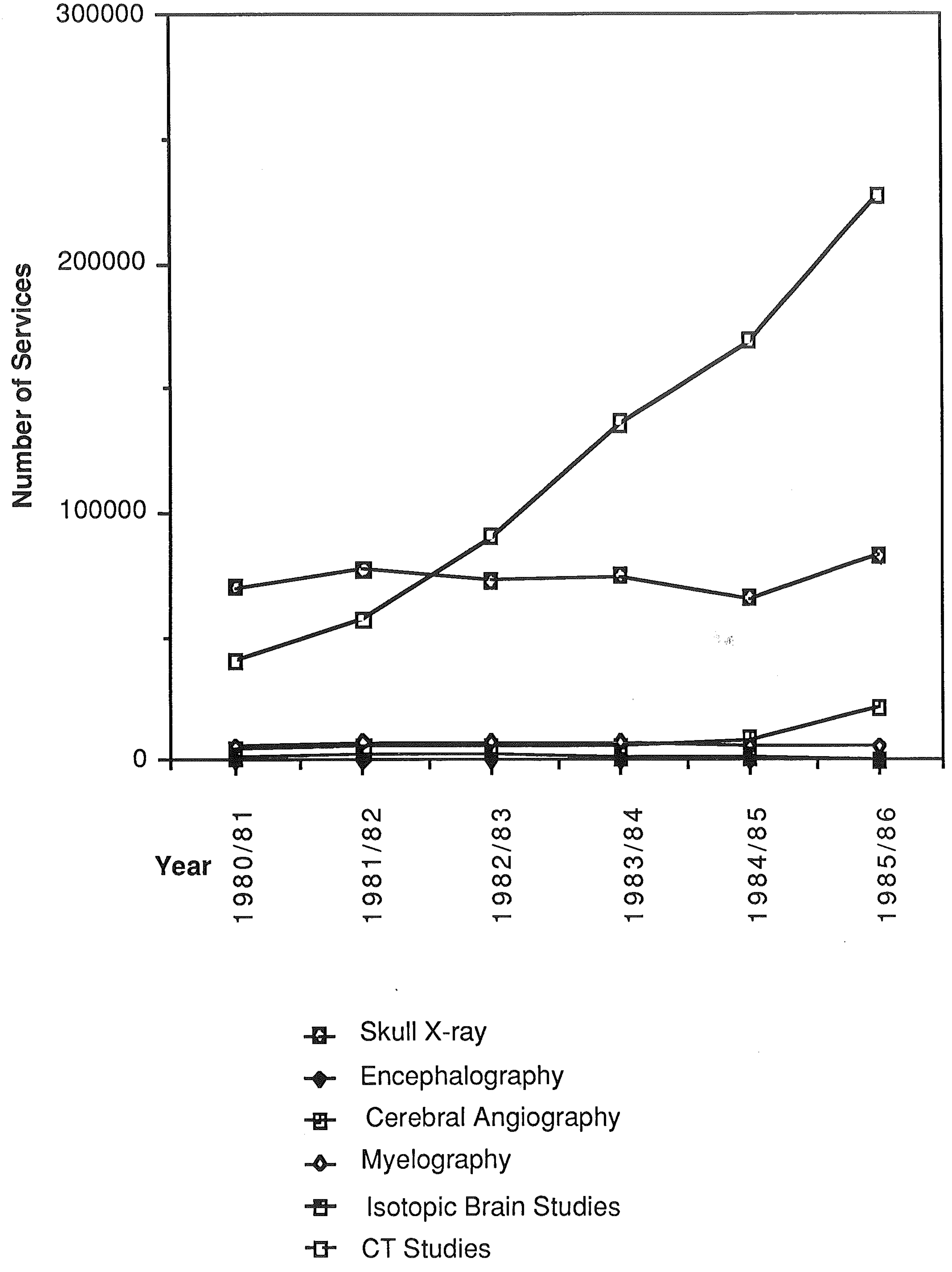
The increase in the number of CT scans since 1980-81 appears to be well over 10 times the number of the identified non-surgical diagnostic procedures that could have been replaced.

The RACR has drawn the attention of the Panel to the replacement of exploratory surgery through the use of CT scanning. The Panel notes that such replacement has been a significant benefit of CT. However, the extent of such replacement of surgery in Australia since 1980/81 is not known and it is uncertain what proportion of CT procedures would have been associated with such gains in patient management.

The increase in CT services since 1980-81 may largely represent an addition to health care services rather than a replacement of other procedures. This addition will have had associated benefits and the Panel is aware that CT has a range of useful applications for which no clear alternatives were previously available. However, more quantitative data would be needed to establish the extent of additional benefit to patients resulting from the increase in CT services.

There was a dramatic increase in the number of cerebral angiograms for which medical benefits were paid from 1983-84 to 1985-86 (Table 13) although earlier hospital figures indicated some replacement of cerebral arteriograms by CT (6). The RACR has advised the Panel that the rise in cerebral angiography is the result of its increasing use in the evaluation of extracranial carotid arterial disease, following the development of surgical management for this condition. CT scanning is used to evaluate intracranial disease but is basically incapable of evaluating the extracranial carotid system.

Fig 5: CT AND ALTERNATIVE PROCEDURES
(MEDICAL BENEFITS DATA)



COSTS OF CT SERVICES

The rapid growth in usage of this high unit cost technology in Australia has inevitably been associated with increasing cost. Because the majority of CT installations are in the private sector, the cost is to a large extent reflected in the benefits paid for CT scans under Medicare. Table 6 shows the substantial growth in medical benefits payments for CT in recent years. In 1986-87 Medicare payments for CT services totalled $67.8 million, representing 24% of all radiology benefits and 2.35% of benefits paid for all services.

TABLE 6
MEDICARE BENEFITS PAYMENTS FOR CT

	1984/85	1985/86	1986/87
Benefits Paid ($M)*	40.37	56.37	67.77
Fees charged ($M)	41.93	58.25	71.42
Fees charged ($M at 84/85 values)**	41.93	53.74	60.26
Number of Scans (thousands)	169.08	227.34	279.38
Fee per scan $	165.2	157.5	143.5

* Figures relate to data processed in each year.

** Fees deflated by Consumer Price Index.

Source: Commonwealth Department of Community Services and Health.

From the data available to the Panel, it is not possible to estimate with certainty the annual cost of CT scans on public patients in public hospitals but the figure may be in the region of $17 million. Thus the total cost to government budgets of all CT services in Australia could be in the region of $85 million. The total cost to Australian citizens, including government costs and individual contributions, would at present be around $90 million per annum.

The use of CT has undoubtedly resulted in some savings which would offset its costs. These would arise from the replacement of other procedures, and from reduced treatment costs resulting from more accurate or earlier diagnoses and avoidance of surgery, or more accurate surgery, or more effective guidance of therapeutic procedures.

In the case of older diagnostic procedures listed in Table 3, the Panel has estimated that annual saving in medical benefits payments for procedures replaced since 1980-81 are in the region of $1 million at current prices. There could be additional savings of around $0.5 million in associated hospital costs. These compare with an increase of about $59 million (at 1987 values) in annual medical benefits payments for CT over the period.

In public hospitals it seems likely that most savings would be associated with procedures replaced before 1980-81, as indicated by Table 10 in Appendix 1. It is possible that these savings are in the region of $5-10 million annually at current prices.

The data available do not allow a meaningful estimate of the savings achieved through reduced treatment costs. Avoidance of exploratory surgery through use of CT would have produced significant, though unknown, additional savings.

SAFETY ASPECTS

There are small but real risks to the patient associated with CT scanning, arising from the use of contrast media and from exposure to ionising radiation.

Contrast media are used in up to 60% of CT examinations in Australia. With conventional ionic media, adverse reactions may occur in 5-8% of patients but in most cases are not severe (9). The RACR (6) has estimated that severe reactions occur in up to 0.03% of patients. On the basis of reported mortality rates of 0.0015-0.009% (9), 3 to 18 deaths could be expected each year in Australia through contrast reactions associated with CT studies, if conventional media were used in all cases.

Newer non-ionic contrast media are considered to be significantly safer, with the risk of death perhaps three times lower than with conventional agents, and ten times lower for high risk patients (10). The RACR (11) has proposed the use of the new non-ionic contrast media with high risk patients.

The Panel supports use of the newer media in high risk patients, but notes that these patients make up a significant percentage of the total, so that the added cost to the health care system would be considerable. The RACR recommendations could imply usage of the newer media in 20,000-30,000 examinations per annum in Australia, at an additional annual cost to health care of perhaps $1.7-2.5 M. It might also be noted that severe reactions are largely unpredictable, and not restricted to high risk patients.

The RACR is undertaking a survey comparing the effects of ionic and non-ionic contrast media in Australia. From the preliminary results, it is evident that there is already substantial use of non-ionic contrast media in Australia. About 13% of the patients included in the survey were in the high risk category, and the new contrast agents were used with nearly 90% of these. The data on complications gathered in the survey show a significant reduction in total and in severe reactions with the non-ionic contrast media. They indicate that the risk of complications is lower for high risk patients receiving non-ionic agents than for low risk patients receiving ionic agents (Benness, personal communication). Details are given in Appendix III.

Lasser et al (12) have recently reported the use of corticosteroids to reduce the incidence of reactions to conventional contrast media. They concluded that the less expensive ionic media, if administered with corticosteroid pretreatment, may serve as a reasonable alternative to non-ionic media, without loss of safety. The Panel has been advised that while steroid pretreatment may prevent allergic reactions it will not affect the organic toxicity of contrast media or prevent resulting cardiac, brain and kidney problems (Benness, personal communication). Clearly, the question of the appropriate use of the newer contrast agents is complex. It has been suggested that an individualised approach should be adopted, with the selection of conventional agent (with or without pretreatment) or newer agent being made in the light of existing conditions and risk factors associated with each patient (13).

The question must be raised as to how many contrast-assisted CT studies undertaken in Australia are essential for diagnosis or decisions on patient management. There is a need for reassurance that patients are not being exposed unnecessarily to a definite risk. It is possible that the savings achieved by a more careful selection of patients for CT studies could offset the additional cost of using non-ionic contrast media.

It is difficult to measure the risk to patients through exposure to ionising radiation from CT scanners, and estimates are generally theoretical. Huda and Sandison (14) have estimated that the radiation detriment through use of a brain scanner was about one induced cancer in 50,000 patients (20 per million). In an Australian study, radiation risk has been estimated for typical examinations with a third generation scanner (15). For head examinations the estimated risk was 56 induced cancers per million patients examined (18 fatal). Higher levels of risk were estimated for chest and abdominal examinations, particularly the chest (193 cancers per million patients examined, 94 fatal).

Certain organs are particularly at risk of radiation detriment in CT examinations. They include bone surfaces and marrow, the lungs, the thyroid, and the breasts and ovaries in women. The risk of serious hereditary effect for pelvic CT examinations of women was estimated to be 400 cases per million persons examined (15). Further details are given in Appendix III.

In the US, a nationwide survey of CT systems is being conducted to determine the average dose from a typical adult head procedure. Overall data to date demonstrate that dose levels for standard head procedures range from 2.4 to 6.6 rads, with dosage level higher for fourth generation than for third generation systems (16). Australian measurements of dose levels for spine procedures have given a wide range of results for different systems. It was observed that image quality increased with dose (17).

It has been suggested that in the USA CT may have contributed to a lowering of total national radiation dose through the replacement of alternative higher dose procedures (18). The Panel notes that where CT scans are largely additive rather than replacements, this is unlikely to have occurred.

There is a need to take account of patient age in assessing risk. Boice (19) has noted that most diagnostic radiology is performed in persons over the age of 40, for whom the risk of inducing cancer is substantially reduced. He suggests that compared to the risks of daily life, the hazards of diagnostic radiography appear trivial. However, he also notes that even a small risk to the individual gains in importance when applied to millions of people, especially if the exposure is avoidable or not clearly associated with demonstrated benefit. He considers that the single most important factor in reducing radiation exposure would be to avoid prescribing clinically unproductive examinations.

The Panel suggests that while the risk to patients through ionising radiation from CT examinations is small, there is a need for referring clinicians and radiolgists to critically consider the importance of proposed CT examinations in the light of the hazard to each patient.

Safety aspects of CT examinations are further considered in Appendix III.

ASSESSMENT OF THE CLINICAL VALUE OF CT SCANNING

Clearly there are many applications in which CT makes a major contribution to health care, and there is general agreement that it is an essential diagnostic technology. However there is a possibility that a significant proportion of services could have been foregone without detriment to patient management or outcome.

While, as described above and in Appendix II, the clinical role of CT has been well established for a number of conditions, less appropriate use of the technology has also been documented in the literature. Benson et al (20) reviewed CT scans of 53 consecutive patients with abdominal pain. Their analysis suggested a low yield from abdominal CT in patients with abdominal pain and no other objective findings. Abdominal CT after unremarkable evaluation for abdominal pain was considered an unnecessary additive diagnostic procedure.

Larson, Omenn and Lewis (21) suggested that CT evaluation of headache patients with normal findings from neurological examinations was expensive and clinically unrewarding in a series of 169 selected subjects.

Hankey and Stewart-Wynne (22) described an Australian prospective study of patients referred to a neurologist, which was undertaken to evaluate the usage of the cranial CT scan in private neurological practice. A total of 826 cases were reviewed. Sixty (7%) had had a CT scan before consultation and 92% of these were referred by the patients' general practitioners. Ninety five per cent of the CT scans were normal. Eighty three patients (10%) were referred for CT after neurological consultation and 91% of these CT scans were normal. The authors question the possible overuse of CT in this area.

Ashworth (23) has reviewed the use of CT in brain scans and noted that scans are unrewarding in patients with trivial symptoms (who sometimes demand an investigation) and that this is often true of scans performed 'for exclusion' in the absence of clinical indications.

Additional data would be desirable to further define areas of application where use of CT is of limited benefit.

The cost to the Australian health care system of CT services is of the order of $90M per annum but little quantitative data are available in Australia on referral patterns for patients undergoing CT, the types of examination requested, the reasons why they are requested, and the clinical value of the results. There seems to be limited information on how CT availability affects the management of patients, and the effect of the recent surge in the number of services on patient care, management and outcome is unknown.

While the technology is mature and well distributed in Australia, in the light of the growing numbers and costs of CT services, there seems a need for a thorough assessment of their contribution to patient care, and cost savings achieved through their use. Such assessment would require detailed and quantitative information on the indications for which patients are referred for CT examinations, the results of these examinations, and their contribution to diagnosis and management decisions. In addition it would be useful to have information on sources of referral and relationship of referral patterns to the clinical impact of the examinations, the use of contrast media, and patient attitudes.

The information required for the assessment could be collected from a randomised sample of radiology practices including both public and private units, and city and regional services.

Assessment of impact on patient management would require interviews with referring clinicians and patients as well as analysis of data from the radiology practices. Such a study would require substantial resources, with involvement of persons expert in sampling and interviewing techniques, and require the support of the RACR and other professional bodies.

EFFECTS OF NEW DEVELOPMENTS

Lower Cost CT Scanners

At present, CT services in this country are in the main performed using scanners such as the GE 9800B costing $1.2M or more, and those such as the Toshiba TCT60 in the $0.7 - 1.0M price range. A recent development has been the production of lower cost CT scanners such as the General Electric CT MAX, intended to produce adequate images for routine use, at around half the cost of most CT units. The CT MAX costs about $0.5M in Australia.

The results of a 1987 survey by the UK Department of Health and Social Security suggest that the CT MAX would perform creditably in routine diagnostic imaging of both the head and the body. It appears that it would give good results in studies of spinal bony structures, but would have limitations in the detection of fine detail in high resolution head scans or in spinal soft tissue studies. This machine is being used in several District General Hospitals in the UK. (Hill, personal communication). Other lower cost scanners are becoming available in Australia.

An earlier lower cost machine, the Meditech M250 Euroscanner, was assessed by Thomson et al (24) and Greensmith et al (25). In comparison with conventional machines, scan speed was slow, so that motion artifact could often be a problem in body scans, and resolution was low, particularly for body scans. There was a high "noise" level in the data. The Panel understands that the Meditech M250 is no longer available.

The Panel suggests that it could be useful for health authorities to consider the desirability of the use of lower cost CT scanners in smaller hospitals and as basic or back up diagnostic tools where higher performance CT scanners are available. There would be a need to take into account expected caseload, repeat referral rate, availability of radiological staff and requirements for high resolution work on more expensive machines.

Quantitative CT

Quantitative CT techniques have been developed for the measurement of bone mineral density in precisely localised sections of bone in spinal vertebrae, and more recently in the hip. The chief aim of such measurements would be to identify patients at risk of developing osteoporosis so that they can be given preventive treatment. (There is no satisfactory treatment for established osteoporosis).

Quantitative CT was discussed in detail in the NHTAP report "Bone Mineral Assessment and Osteoporosis" (26). Although quantitative CT can identify and measure existing osteoporosis, the Panel was unable to conclude that any existing technique could reliably be used to detect developing disease, predict the risk of osteoporotic fracture, or identify women who should be given preventive treatment. It would, however, have a useful role in research.

Cine CT

High speed or cine CT was designed at the University of California specifically for cardiac applications, which required a capacity to "freeze" cardiac motion and produce images free of motion artifact.

In cine CT, the rotating X-ray beam is produced by electromagnetically sweeping a sharply focussed electron beam along a tungsten target partially curved about the patient. With each sweep, two contiguous CT images are produced simultaneously. There are four parallel targets so that eight slices can be rapidly imaged without moving the patient (27).

Cine CT can be used in several cardiac applications, including measurement of myocardial perfusion, and quantitation of myocardial infarction. In all its applications, contrast medium is required (27). It has been suggested that cine CT could also find application in examinations of trauma and pediatric patients when high speed is needed, and in dynamic upper airway studies (28).

In cardiac applications, it would appear that cine CT would compete principally with nuclear medicine techniques, over which it would have the advantage of higher spatial resolution. In some applications it may be an alternative to angiography while in the future it may have to compete with magnetic resonance imaging. The disadvantages of cine CT include its high cost, reliance on contrast media and ionising radiation, inflexibility of the usual views recorded, and continuing problems with beam hardening artifacts (28). It is not yet possible to determine the potential contribution of this modality to patient care.

3-D Imaging

With a number of commercially available CT units, it is now possible to construct three dimensional (3-D) images from multiple slices, by using special software. Production of the images involves some "smoothing" of data and loss of accuracy. In addition, the large number of thin slices required results in increased radiation dose to the patient, as well as increased time and cost (29).

It seems unlikely that in the short term 3-D imaging will have a role in diagnosis, but it may be useful in limited areas of therapy planning, particularly in orthopaedic and cranio-facial surgery and in radiation therapy.

Effect of MRI Availability

The development of MRI has provided a potential alternative to CT for a number of applications. While development of MRI is still continuing rapidly, it is evident that it is capable of producing excellent diagnostic information, some of which may be unique.

However, diffusion of MRI in the USA has been slow compared with CT at a similar stage of development (30). The reasons are complex and include clinical, technical, economic and regulatory factors. Whereas CT was a major breakthrough in imaging, MRI has been introduced into health systems where tomographic services are already widely available. While the newer technology shows great potential, benefits as compared with CT and other modalities may be marginal in a number of applications, and the clinical role of MRI is not yet fully established.

The modality is slower, more complex and less easy to use than CT, technical development is still rapid and there is not yet consensus on which magnet type is appropriate. MRI scanners have high capital and operating costs, and government regulatory and reimbursement policies on use of high cost technologies have become more stringent.

Further developments in magnet design and software may lead to cost decreases, although it seems possible that there could be a counter trend with evolution of fast scan sequences and options for spectroscopic applications, leading to more expensive installations. A range of MRI devices of varying cost and complexity may become available and there is some feeling that dissemination of the new technology may be inhibited unless cheaper and more easily operated scanners emerge.

It continues to be difficult to base judgment of future MRI use in Australia on overseas data. Earlier US estimates of up to 66% replacement of CT by MRI have not so far proved accurate. For a number of applications it is likely that MRI will be additive to CT with patients undergoing sequential scanning.

In view of the cost and uncertainty associated with MRI services, the Panel considers that MRI may produce little or no change in the requirements for CT scanning in this country over the next 5 years, other than for applications in those conditions where MRI provides overwhelming advantages in imaging.

Effect of Developments in Nuclear Medicine

Australia's first medical cyclotron facility is planned to become operational in 1990, at the Royal Prince Alfred Hospital, Sydney. It will produce positron-emitting radioisotopes for use in positron emission tomography (PET) as well as certain photon emitting istopes for use in nuclear medicine.

The availability of PET in Australia is unlikely to have significant impact on usage of CT. The Panel expects that at most only two PET units would be established in this country in the foreseeable future. They would be used for medical research, with some limited clinical applications such as the assessment of patients with refractory epilepsy for surgery.

Single photon emission computed tomography with newly developed technetium - 99m radiopharmaceuticals or cyclotron-produced iodine -123 can be used to image cerebral blood flow. In the future this technique may be used in the assessment of stroke patients and could to some extent replace CT in this application.

CONCLUSIONS

It is beyond doubt that CT scanning is now a key modality in diagnosis and disease management. CT services should be available to all Australian patients who would benefit.

While the technology is widely disseminated in Australia, with the numbers of scanners per capita equivalent to or higher than for most other countries, there appears to be scope for improving the pattern of distribution. In particular, there is a need for Health Authorities to keep public hospital CT facilities under review, and to ensure that numbers and technical quality of scanners in that sector are adequate.

There may also be a need to widen the coverage of CT services to include more country areas. Efficient use in smaller centres will depend on availability of suitably trained staff, selection of appropriate equipment and presence of a realistic case load.

Lower cost CT scanners are now available. These have lower technical capability than the more expensive machines, but may be able to provide effective diagnostic coverage in many situations. Their role in health care services merits careful consideration by government and professional bodies.

While there is some feeling within the radiology profession that CT should become even more widely disseminated, becoming a more basic diagnostic tool, the Panel suggests that replacement of plain X-ray and other cheaper examinations with CT requires careful justification, taking into account diagnostic yield in various situations, effect on patient management, patient safety, relative cost and training and quality requirements.

The extent to which the recent substantial increase in the number of CT services performed in Australia can be accounted for in terms of use for essential diagnostic and staging purposes is uncertain. Several factors appear to have contributed to the increase. A significant factor has been the view that CT is a major advance, of proven value in many situations, and that all appropriate information should be made available for decisions on patient management. As discussed above, CT has replaced inferior older diagnostic methods and some exploratory surgery.

The Panel considers that, in addition, the growth in CT services in part reflects government policies on financing and the broad basis for referral of patients for such services. With greater availability of CT services, it is possible that some ordering of examinations by referring physicians is not wholly appropriate, and availability of further education on the scope and limitations of CT data would be desirable. A further reason for growth is that a CT scanner is regarded as essential equipment by all major private radiology practices to avoid loss of referrals to competing practices. Delays in installing or upgrading public hospital CT facilities would have contributed to the growth in numbers of private sector scanners in some States.

There are few data linking CT examinations with patient management and outcome, and virtually no information on the type of patient presenting for examinations, or the physician's reason for referral. Australia is therefore faced with continuing growth in use of a diagnostic imaging technology without any clear measure of the extent of benefits. There is also limited information on which types of patient have access to CT, and on which examinations might be marginal in comparison with other types of investigation.

The history of the introduction of CT services in Australia and the complex issues associated with their current distribution and use suggest the need for governments to take appropriate initiatives in dealing with the introduction of future new high cost technologies. Such initiatives should include detailed initial assessment, ongoing data collection and appraisal and consultation with those organisations with major interests in use of the technologies.

The Panel suggests that it would be desirable to establish a study to obtain patient, referral, diagnostic, management and cost data from a wide range of CT services in Australia. To be useful to governments, administrators and professional bodies, such a study would need to draw on information from a large number of CT practices, selected at random, with follow-up of patients and referring physicians. The expense of such a major health services evaluation (perhaps $400,000) would need to be seen in the context of expenditure nationally on CT services, currently of the order of $M90 per annum. Data from such a study would be of major value to those responsible for planning and operating CT services.

The Panel sees a need for guidelines for referring medical practitioners on the appropriate indications for CT examination, including advice on risks, costs and benefits. Preparation of such educational material might be considered by relevant professional bodies including the Royal Australasian College of Radiologists, the Royal Australasian College of Physicians, the Royal Australasian College of Surgeons and the Royal Australian College of General Practitioners. The Panel would also favour publication of data on CT from Australian sources as an aid to education of users of the technology.

APPENDIX I

DATA ON USAGE OF CT IN AUSTRALIA

TABLE 7
NUMBER OF CT SERVICES FOR WHICH MEDICAL BENEFITS HAVE BEEN PAID : 1980/81 - 1985/86

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87*
NSW	18,108	25,395	40,657	62,500	73,736	100,723	126,426
VIC	9,712	15,363	23,847	33,735	38,771	47,822	57,726
QLD	4,182	5,453	9,127	16,105	22,440	32,746	38,689
SA	3,182	5,314	8,477	11,915	14,445	20,129	24,583
WA	3,871	4,767	6,096	8,400	11,732	16,226	20,245
TAS	479	744	1,334	3,161	3,738	4,839	5,759
ACT					3,088	3,814	4,559
NT					804	630	1,011
U/OS**	87	123	220	282	325	408	382
AUST	39,621	57,159	89,758	136,098	169,079	227,337	279,380

Source : Commonwealth Department of Community Services and Health

* Figures relate to data processed in each year
** Unidentified or overseas

TABLE 8
CT EXAMINATION IN PUBLIC HOSPITALS
BY STATE

NUMBER OF SCANS

STATE*	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
NSW	5703	6364	8666	17618	21983	26463
SA	5131	5271	10464	11235	11397	11953
WA	4305	5737	8239	9220	8993	6485
TAS	1968	2271	2419	2624	2644	2262
QLD	4897	5124	6131	9062	11197	11844
VIC	8283	14532	18922	23146	28127	28310 (est)
ACT		2657	2858	2204	1221	3064
TOTAL	30287	41956	57699	75109	85562	90380 (est)

* NT figures not available

Source : State and Territory Health Authorities

TABLE 9
CT SERVICES AS A PERCENTAGE OF
ALL MEDICAL BENEFITS SERVICES

YEAR	TOTAL SERVICES	PERCENTAGE CT SERVICES
1980/81	81,062,524	.049
1981/82	93,092,595	.061
1982/83	96,087,065	.093
1983/84	109,846,527	.124
1984/85	113,698,638	.149
1985/86	121,388,963	.187
1986/87	128,641,824	.217

Source : Commonwealth Department of Community Services and Health.

TABLE 10
CT SERVICES FOR WHICH MEDICAL BENEFITS WERE PAID BY TYPE OF SCAN AND TYPE OF SCANNER

TYPE OF SCAN	NO OF SERVICES (PERCENTAGES OF TOTAL FOR YEAR)	
	Brain Scanner	Body Scanner
1980/81		
Brain Scan		
- plain only	1,262 (3%)	3,523 (9%)
- with contrast	5,592 (14%)	20,885 (53%)
Body Scan		
- Plain only		2,861 (7%)
- with contrast		5,499 (14%)
1985/86		
Brain Scan		
- plain only	715 (0.3%)	19,274 (9%)
- with contrast	724 (0.3%)	96,960 (43%)
Body scan		
- plain only		56,923 (25%)
- with contrast		52,741 (23%)

Source : Commonwealth Department of Community Services and Health

TABLE 11
CT SERVICES IN CERTAIN PUBLIC HOSPITALS
IN 1985/86 : DISTRIBUTION BY TYPE OF SERVICE

TYPE OF EXAMINATION	PERCENTAGE OF ALL EXAMINATIONS			
	Royal Canberra	Townsville	Austin	Central Gippsland
Brain Scan				
- plain	47	38	38	2
- contrast	15	19	26	50
Body Scan				
- plain	30	28	22	26
- contrast	8	15	14	22

Source : State and Territory Health Authorities

TABLE 12
NUMBER OF CT SERVICES PER THOUSAND POPULATION IN 1985/86 AND 1986/87

STATE	SERVICES UNDER MEDICARE		SERVICES IN PUBLIC HOSPITALS
	1985/86	1986/87	1985/86
NSW	18.3	22.7	4.8
VIC	11.5	13.8	6.8
QLD	12.7	14.8	4.6
SA	14.7	17.8	8.7
WA	11.4	13.9	4.6
TAS	10.9	12.8	5.1
ACT	14.7	17.6	11.8
NT	4.3	6.9	NA
AUST	14.3	17.3	5.7

TABLE 13
NUMBERS OF TESTS, MAJOR AUSTRALIAN TEACHING HOSPITAL, 1976/77 TO 1986/87

	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Total X-ray Examinations	76,365	83,920	90,993	86,892	86,890	75,791
CT Head	_	_	1,960	2,259	2,522	2,377
CT Body	_	_	665	1,115	1,731	1,525
Radio Isotope Brain Scan	2,678	2,437	1,208	652	366	200
Skull X-rays	3,712	3,439	3,156	2,688	2,585	2,300
Electroencephalograms	1,929	1,643	1,714	1,674	1,597	1,465
Neuroangiograms	1,131	1,456	443	370	486	583
Pneumoencephalograms	85	40	5	4	-	-
Myelograms	262	371	357	340	308	356
Lymphograms	63	110	153	92	27	19
Abdominal Arteriograms	110	145	143	160	151	298
No. Inpatients Treated	23,011	26,998	30,012	30,013	31,237	

TABLE 13
NUMBERS OF TESTS, MAJOR AUSTRALIAN TEACHING HOSPITAL, 1976/77 TO 1986/87 - CONTINUED

	1982/83	1983/84	1984/85	1985/86	1986/87
Total X-ray Examinations	79,779	87,063	90,481	93,909	93,994
CT Head	2,092	1,546	2,269	2,218	2,229
CT Body	1,380	866	1,742	1,834	2,029
Radio Isotope Brain Scan	51	93	25	22	6
Skull X-rays	2,607	3,216	3,240	3,045	2,917
Electroencephalograms	1,462	1,608	1,295	1,337	1,384
Neuroangiograms	749	863	895	954	885
Pneumoencephalograms	-	-	-	-	-
Myelograms	413	352	293	324	305
Lymphograms	2	5	7	3	-
Abdominal Arteriograms	320	431	409	417	372
No. Inpatients Treated					37,533

Sources : RACR Statement on CT Scanning, 1984 and WA Sorby, personal communication

TABLE 14
ALTERNATIVE PROCEDURES : NUMBER OF TESTS FOR WHICH MEDICAL BENEFITS WERE PAID 1980/81 TO 1985/86

PROCEDURE	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Skull X-ray	69,807	76,977	73,177	74,230	65,409	82,481
Encephalography	99	121	84	69	35	38
Lymphangiography	554	555	432	331	220	260
Cerebral Angiography	4,034	5,103	5,481	5,773	8,489	21,866
Myelography	5,943	7,062	7,220	6,490	5,372	6,114
Isotopic Brain Studies	1,452	3,133	2,268	1,520	1,047	676
CT Examinations	39,621	57,159	89,758	136,098	169,079	227,337

Source : Commonwealth Department of Community Services and Health

APPENDIX II

APPLICATIONS OF CT

APPLICATIONS OF CT

The RACR has advised that in the following examinations, CT is the appropriate modality, with conventional x-ray imaging having little to offer (Jones, RACR, personal communication).

The Cranial Cavity and its Contents

The brain substance for tumours, infarcts, infections, demyelinating disorders, trauma and hemorrhage.

The ventricular system for hydrocephalus.

The pituitary gland for tumours or infarcts.

The cranial nerves particularly the seventh and eighth for tumours.

The meninges for tumours and haemorrhage.

The skull for displaced fractures.

The Facial Structure

The orbits and their contents, for tumours, infections and Graves' disease.

The paranasal sinuses, for complicated inflammatory disease or mass lesions.

The facial bones, for complex fractures and destrucive processes.

The post nasal space for mass lesions.

Base of Skull

The petrous bones particularly for middle and inner ear maldevelopment, infections and tumours.

The clivus and floors of anterior and middle cranial fossa, particularly for destructive bone processes and trauma.

Neck

The larynx, for carcinoma and trauma.

The thyroid particularly for mass lesions, and estimation of restrosternal extension of goitres.

Lymph nodes for primary and secondary tumours.

The Thoracic Cavity

The mediastinum particularly for vascular abnormalities, infiltrating mass lesions and lymph node enlargement.

The lungs especially for those areas hidden from view on chest x-ray, in particular the anterior and posterior costomediastinal recesses and in the evaluation of complex or ill defined pulmonary abnormalities.

The pleural cavity particularly for the evaluation of plural effusions, pleural mass lesions and pleural calcification.

The Abdominal and Pelvic Cavities

Solid organs, for trauma, inflammatory processes, tumours.

Lymphatic tissue particularly of the retroperitoneum involved by primary and second tumours.

The peritoneal cavity particularly for evaluation of ascites and inflammatory and neoplastic processes involving the wall of the gut and the peritoneal cavity itself.

Extremities

Soft tissues, particularly for the evaluation of undiagnosed soft tissue masses, and assessment of the soft tissues in destructive bone lesions.

Bones

For the evaluation of complex pathologies such as bone tumours, and evaluation of the soft tissue changes in destructive bone lesions.

For complex fractures.

Spine

Bone destructive lesions; bone destructive lesions are commonly not seen in plain x-rays until they are 2-3 cm in size. CT however, commonly demonstrates lesions as small as 5 mm.

Neurologic disorders, such as syringomyelia, radiculopathy, myelopathy for which CT myelography is sometimes performed.

Pain; in the assessment of pain, plain radiographs of the spine are limited to the demonstration of longstanding degenerative disease, trauma and focal bone destructive lesions. They are insensitive to early bone destructive lesions and to osteoarthritis in facet joints until well advanced. Significant pathology revealed by CT includes less advanced disc degenerative changes, early facet joint osteoarthritis, disc prolapse with or without accompanying nerve root compression, and spinal canal stenosis.

Details on some of the major areas of application are given below.

Head Trauma

Skull radiography has been widely used in the assessment of patients with head trauma, but although it can detect skull fracture, it cannot visualise intracranial injury. However, in head trauma patients, the need for medical or surgical intervention depends on the presence of intracranial conditions such as haemorrhage or oedema. These conditions often cause death or disability which could have been prevented by appropriate intervention. They can be visualised with CT.

American studies have shown that in head trauma patients with definite signs of intracranial injury, CT scanning has reduced the need for surgical intervention by 58%, skull radiography by 80%, and cerebral angiography by 84% (31).

Imaging services can be used inappropriately with head injury patients, and the need for guidelines has been recognised. In 1979 the US Food and Drug Administration (FDA) appointed a panel of expert physicians to examine this issue. The panel developed a management strategy in which patient history, physical and neurological examinations were used to assess the risk of intracranial injury. Groups at high, low and moderate risk were defined (31).

The high risk group are patients with severe head injuries and clear abnormalities such as depressed levels of consciousness and focal neurological signs. In this group skull fractures are common and highly correlated with intracranial injuries. High risk patients require immediate neurosurgical examination, CT scanning, or both. Skull radiography is of minimal usefulness.

The low risk group comprises patients with trivial injuries and minimally abnormal findings on physical and neurological examination. These patients have virtually no likelihood of intracranial injury and radiographic examination is not considered necessary.

The moderate risk patients are less well defined. They may include patients which do not meet the high risk selection criteria but for whom there may be significant findings such as possible depressed fracture. They should be kept under observation to detect any signs of deterioration, and neurosurgery or CT should be considered.

When these criteria were applied in a prospective study to 7035 head trauma patients in US hospitals, no intracranial injuries were discovered in any of the low risk patients (31). The study was primarily concerned with the rational use of skull radiography but clearly has implications for CT. There is a danger that with increasing reliance on CT it could be used routinely in examinations of low risk patients.

Stroke

Although CT can determine the site and extent of a cerebrovascular lesion, the value of this information is questionable if there is no effective therapy. Studies by Larson et al (32) and Hazelton and Earnest (33) indicated that CT had no statistically significant effect on management or outcome for stroke patients. However these studies drew on data from the period 1974-1979. Developments in management practices since that time may allow more effective use of CT data.

An argument for the use of CT in the investigation of stroke patients is that it can exclude treatable conditions such as tumours or subdural haematomas which occasionally produce the symptoms of stroke. Britton et al (34) found that CT discovered few but important errors in stroke diagnosis and considered that it should be used as the sole investigation when stroke patients are admitted to hospital.

Sandercock et al (35) found that CT detected nonstroke lesions in 1.5% of 325 cases diagnosed as stroke. They concluded that CT could provide information which would be used in management in up to 28% of patients but that it was unnecessary to scan all patients with stroke. They suggested that patients could be selected for CT if the diagnosis was doubtful because of inadequate clinical history, there was a possibility of treatable cerebellar haemorrhage, there was atypical deterioration, or to exclude haemorrhage in patients on haemostatic drugs or being considered for carotid endarterectomy.

Diagnosis And Management of Cancer

A major role has been established for CT in the diagnosis and management of cancer. For example in the UK approximately 60% of all body CT referrals are in-patients with known or suspected cancer (36). CT is used in primary diagnosis, staging disease, guiding biopsies, and planning radiotherapy.

In the area of primary diagnosis, contrast enhanced CT has become the technique of choice for the detection of intracranial tumours. It has clear advantages in terms of increased accuracy or reduced risk to the patient, over the older alternatives of skull radiography, pneumoencephalography and cerebral arteriography (37). In addition it has made diagnosis less difficult and reduced the the number of investigations required (38,39). In the future MRI may have an increasingly important role in this application.

Cancer in other parts of the body is usually diagnosed before referral for CT. However, CT may be used to detect abdominal masses, adrenal tumours, and other hormone producing tumours (37). The Urological Society of Australasia (40) has noted that CT is particularly useful in the diagnosis of cancer in the kidney.

CT has important applications in the staging of cancer, but accuracy is heavily dependent on the anatomical site. It is more effective than other techniques in detecting local spread of tumours of the bladder, head and neck, pancreas and kidney. In cases of lung cancer CT can identify inoperable disease more accurately than was previously possible, reducing unnecessary surgery. Metastases in lymph nodes may be diagnosed with CT, provided the nodes are enlarged (37). Metastases to the lungs, liver, skeleton and brain can be identified with CT, but the sites where it has made the most impact are the brain and the lungs. Pulmonary metastases as small as 3mm in diameter may be detected (41). In staging carcinoma of the bladder, it can help determine whether lymph nodes in the mediastinum are involved, and whether radical surgery or a more palliative form of management should be chosen (Pegg, personal communication).

CT has proved to be an excellent technique for measuring changes in tumour size as a response to treatment, particularly in sites previously inaccessible to observation. However, it has important limitations. CT scans may be very difficult to interpret in patients who have received radiotherapy, and residual cancer may be missed. In addition, CT may not resolve small volume disease in some regions, particularly the pelvis (37).

The impact of CT on the management of cancer patients has been measured in several studies. Male et al reported that CT provided unique diagnostic information in 50% of 1030 examinations of cancer patients, and 14% of scans led to a change in patient management. Husband has reported that CT directly altered management in 23% of 77 patients with soft tissue sarcomas, and 30% of 126 patients with testicular tumours (37).

Radiotherapy Planning

Several studies have shown that CT scanning contributes to treatment planning in a significant proportion of radiotherapy patients. In a prospective study of 77 patients at Massachusetts General Hospital, a preliminary treatment plan was developed for each patient on the basis of conventional studies, a CT scan was performed , and its effect on the treatment plan was evaluated. In 52% of cases, the treatment plan was changed as a result of the CT scan (42). Percentages found in similar studies were 38% (43,44) and 44% (45).

Goitein also considered the effect of CT on patient outcome and its cost benefits (42). There had been no clinical studies of the impact of CT in radiotherapy planning on patient outcome.

However, using probabilities of achieving local tumour control with adequate and inadequate coverage of the tumour by radiation, he estimated that the use of CT resulted in a 6% improvement in local tumour control. Taking into account the mortality from disseminated disease in spite of local control, he estimated that the use of CT improved average 5 year survival rates by 3.5%. At the same time CT increased the cost of radiotherapy by only 2.1%. From the estimated costs of the additional treatments required for those whose radiotherapy failed, Goitein calculated that CT scanning costing $US250 saved on average $US1140, a cost-benefit ratio of 4.6.

Abdominal Studies

For the detection of localised collections of abdominal fluid such as abscesses and collections of blood, serum or bile, ultrasound and radionuclide scanning as well as CT are available. The choice of the optimal sequence of techniques is complex and depends on a number of technical and clinical factors (46). CT has become an extremely valuable tool for the guidance of percutaneous aspiration of abdominal fluid , particularly in small or deep-seated collections (47). The procedure may replace laparotomy and can be of particular value, for example, in the case of ill patients who have developed abscesses after previous surgery and whose survival may be jeopardised by a further operation (Pegg, personal communication).

In liver studies CT may have little advantage over radionuclide scanning or ultrasound, but it has been shown to be valuable in defining renal lesions. It is superior to ultrasound in the detection and identification of pancreatic disease. Several studies have shown it to be an accurate and safe procedure for guiding biopsies of masses in abdominal organs (46,47).

CT has virtually replaced other imaging methods including radionuclide scanning and angiography in the evaluation of blunt abdominal trauma. In a study covering all trauma patients admitted to San Francisco General Hospital in 1983, CT was performed when significant abdominal injury was suspected and patients were stable. Unstable patients proceeded immediately to surgery, while patients with minor injuries did not receive CT. Of 940 blunt trauma patients, 125 (13%) underwent CT examination. Of these, 50% gave negative scans. The introduction of emergency abdominal scanning at the hospital substantially reduced the number of exploratory laparotomies perforned after blunt abdominal trauma, from 231 in 1975-76 to 74 in 1983 (48).

Spinal Studies

CT has attraction as a less invasive alternative to myelography for studies of spinal disc herniation and stenoses. Early results were disappointing, with poor resolution of spinal canal soft tissue. Much improved images were subsequently achieved as technology with high contrast resolution was developed.

Simeone and Rothman (49) considered that CT alone could be used in the assessment of patients for lumbar spinal disc herniation, if the symptoms included pain and neurological deficit, and the CT scan clearly showed the responsible abnormality. In patients with less well developed symptoms,which persist after a trial of bed rest, CT could be used to determine whether myelography was necessary. CT was considered helpful but not a substitute for myelography in the evaluation of patients with lumbar spinal stenosis. It was found to be of great value in the post-operative evaluation of the lumbar spine.

It has been noted that because 30 to 40% of CT scans, myelograms and diskograms in asymptomatic subjects show abnormalities, a positive imaging study is not diagnostic unless it conforms to the clinical syndrome (50).

In a comparison of CT, with and without intrathecal contrast medium, and myelography in the diagnosis of cervical disc herniation, CT without contrast medium gave the highest sensitivity and specificity for the particular group of patients examined (51). The authors concluded that CT is at least as effective as myelography, except possibly in patients with large shoulders and suspected C7-T1 disease.

Of the applications of CT mentioned in this Appendix, all except diagnosis of lumbar and cervical disc protrusion are likely to be frequently performed in Australia only at major referral centre hospitals.

APPENDIX III

SAFETY ASPECTS OF CT SCANNING

SAFETY ASPECTS OF CT SCANNING

Contrast Media

The data in Tables 7-12 of Appendix I indicate that contrast media are used in 50-60% of CT examinations in Australia. There is a small but definite risk associated with the use of contrast media. Indeed it is possible that their use in CT scanning results in more detriment to patients than the radiation exposure (14).

The detrimental effects of conventional ionic media include pain and discomfort, sensitivity-type reactions ranging from skin reactions to bronchospasm, and effects on specific organ systems, particularly the heart and kidneys. Estimates vary of the percentage of patients who suffer complications related to these contrast media. McLennan (9) gives figures of 5-8% but notes that in most cases the effects are mild or moderate. The RACR (6) has suggested that severe reactions occur in up to 0.03% of patients examined. Reported mortality rates range from one in 11,000 for a study on intravenous administration of contrast to one in 66,000 for a study on urography and CT studies (9).

It is not possible to predict with certainty whether an individual patient will have an adverse reaction to contrast media, but the risk is increased in certain groups. The RACR (11) has identified the following as high risk:

* infants and small children
* patients with renal or cardiac impairment
* poorly hydrated patients
* patients with diabetes mellitus, myelomatosis, or sickle-cell anaemia
* asthmatics
* patients with a significant history of allergy
* patients with previous reactions to contrast media

The adverse effects of contrast media are believed to be largely associated with their osmolality (the relative number of particles they produce in solution). New agents with significantly reduced osmolality compared to the conventional media have now been introduced. They include the non-ionic agents iopamidol and iohexol, and the dimeric ionic substance ioxaglate. Animal and *in vitro* studies indicate the new agents have substantially reduced chemo-, neuro-, cardiac and renal toxicity. In humans, the non-ionic agents are reported to significantly reduce nausea, vomiting and skin reactions, while all give decreased cardiovascular and neurological reactions (10). At the same time diagnostic efficacy is unchanged or improved (9). It has also been suggested that the new non-ionic media are safer than metrizamide for intrathecal studies.

Manufacturers' statistics indicate that with the new agents, mortality is greatly reduced. One death in 300,000 doses has been recorded for iohexol and one in 2 million for iopamidol (9). However these figures are based on reporting systems which are inevitably subject to inaccuracies, particularly from under-reporting. Wolf (10) has suggested that the risk of death with the new agents may be at least three times lower overall than with the conventional agents, and as much as ten times lower in high risk groups.

In comparison with conventional ionic media, the new low osmolality agents are four times more expensive in Australia. (In the USA they are 16-20 times more expensive.) They are, however, comparable in cost to metrizamide.

There has been some criticism of claims for the new low-osmolality agents. White and Halden (52) have noted that clinically significant adverse effects such as renal failure have not been documented to be more frequent with the conventional media than with the new agents. They have suggested a need for randomised double-blind trials in high-risk patients, comparing renal, cardiac and allergic reactions for the two types of agent.

It is accepted that in the light of the high cost of the new agents, their improved safety should be clearly established before their use is promoted. However, the scientific evidence for their greater safety is considerable, and the general consensus among radiologists appears to be that it is established (eg 11). In these circumstances ,the ethics of randomised trials in high-risk patients may be questionable. It could be more appropriate to continue the collection and analysis of data on the effects of the new contrast media, for large numbers of patients. Australian radiologists are participating in a data collection program organised by the RACR, aimed at comparing the effects of ionic and non-ionic contrast agents for high and low risk patients. Preliminary results are now available and are summarised in Tables 15 and 16.

In a multi-institutional randomized study, the protective effects of pretreatment with corticosteroids against reactions to intravenous contrast media have been determined (12). A two-dose regimen significantly reduced the incidence of reactions of all types, and the incidence of reactions requiring therapy was similar to that reported for patients receiving non-ionic medium.

TABLE 15
RACR INTRAVENOUS CONTRAST MEDIUM SURVEY, 1987
NUMBER OF PATIENTS WITH REACTIONS

CATEGORY OF PATIENTS	NO. OF REACTIONS					TOTAL NO. OF PATIENTS
	NONE	MILD	MODERATE	SEVERE	DEATH	
Ionic Agents						
Low risk	43,691	1461	109	41	2	45,304
High risk	882	54	19	3	0	958
Non-ionic Agents						
Low risk	7624	98	9	0	0	7,731
High risk	6888	108	9	2	0	7.007
Total	59,085	1721	146	46	2	61,000

TABLE 16
RACR INTRAVENOUS CONTRAST MEDIUM SURVEY, 1987
PERCENTAGE OF PATIENTS WITH REACTIONS

CATEGORY OF	PERCENTAGE OF REACTIONS		
	MILD	MODERATE	SEVERE
Ionic Agents			
Low risk	3.2	0.24	0.09
High risk	5.6	1.9	0.31
Non-ionic Agents			
Low risk	1.5	0.13	_
High risk	1.3	0.12	0.03

Ionising Radiation

Evens and Mettler (18) reviewed radiation exposure from CT scanning in USA for 1983, made up of 5-5.5 million procedures with 63 percent head scans, 27 percent body and 10 percent spine, including perhaps 500,000 high resolution examinations. They estimated that CT scanning contributed 7-8% of the adult bone marow dose received from diagnostic radiology. CT had replaced alternative high and low dose examinations and Evens and Mettler suggest that CT may have contributed to a lowering of the total national body burden of radiation, even though inherent CT doses are relatively high. Data on this matter were not available. These authors note the need to take account of patient age in assessing risk. Overall surface dose varied widely, ranging from 10-70 mGy for most examinations. An earlier survey of scanners available in Australia (53) gave peak dose figures that generally fell within the range quoted by Evens and Mettler.

More recently, Morris and Rafferty (17) have measured radiation doses for spinal imaging for 6 commercial scanners, using a phantom. Absorbed radiation doses ranged from 36 to 131 mGy. Jacobsen and Kelly (54) have noted the need for dissemination of meaningful quantitive radiation dose data on new generation CT units and possible problems in making meaningful estimates of patient exposure. They conclude that for recent CT units, radiation levels outside the scanning room are not a problem but that in-room occupancy by clinical personnel requires a prior knowlege of radiation level at various occupancy sites. Use of 'optimum technique factors', such as slice thickness and exposure time, is essential to minimize patient exposure. It is suggested that determination of phantom surface exposure for installed CT units would provide a vital monitoring parameter for achieving lowest possible patient exposure.

Huda and Sandison (14) developed a risk-related approach to CT dosimetry which took acount of non-uniform dose distribution in the body and the relative sensitivities of different organs and tissues. Using as an example an EMI 5005 scanner, they estimated a total throughput of 50,000 patients, with 60% positive diagnosis and a radiation detriment of about one induced cancer with negligible genetic effect.

Rafferty (15) has estimated the radiation risk for typical head, chest, abdominal and pelvic exminations on the basis of measurements of mean organ doses using a Siemens Somatom DR-H and a phantom. International data on risk for different organs per 1000 mGy were used to determine radiation risk for each type of examination. The results are summarised in Tables 17 and 18 below.

TABLE 17
CANCER RISK PER MILLION PERSONS EXAMINED

SCAN TYPE	FATAL CANCERS	NON-FATAL CANCERS
Head	18	38
Chest	94	99
Chest (Female)	139	144
Abdomen	72	58
Pelvis	65	45

Source : M W Rafferty, " Radiation Risk Estimates from CT Studies", Paper presented at the 38th Annual National Congress of the Australian Institute of Radiography, 1987.

TABLE 18
RISK OF SERIOUS HEREDITARY EFFECT
PER MILLION PERSONS EXAMINED

SCAN TYPE	FEMALES	MALES
Head	2	2
Chest	6	4
Abdomen	280	40
Pelvis	400	60

Source : As above

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