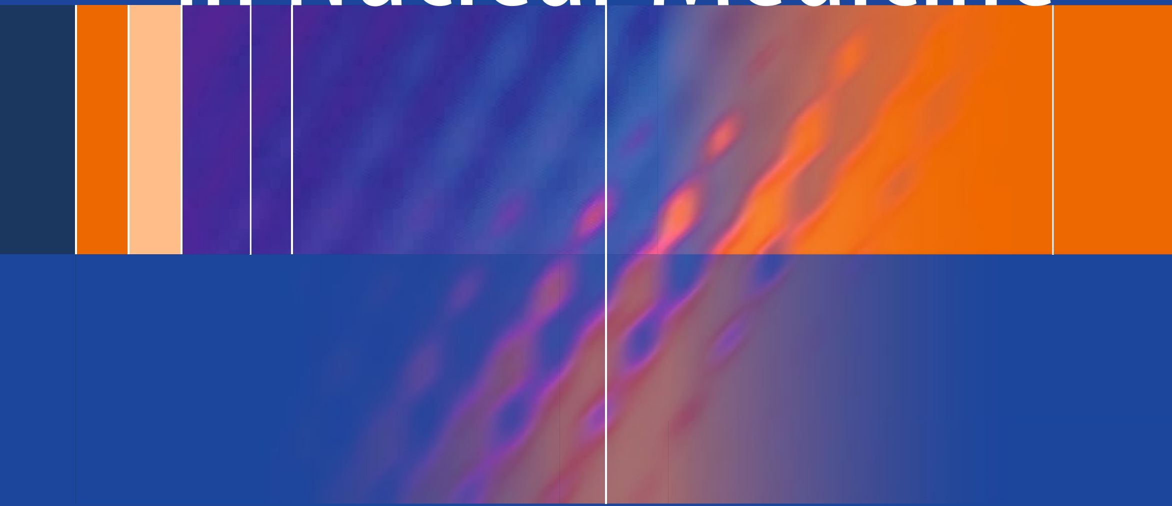
Practical SPECT/CT in Nuclear Medicine



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This book has taken over two years to produce and without the sustained hard work from the authors this would have not been possible. The authors have gone to great lengths to source and organise their information to deliver interesting, valuable and digestible narratives for the reader. On this basis we should like to thank all the authors. In particular we should like to express sincere gratitude to one of the authors - Professor Richard Lawson, particularly for his significant contribution to radiographer and nuclear medicine technologist education and training. Richard, a physicist from Central Manchester University Hospitals NHS Foundation Trust (UK), has freely given time and energy to encourage and develop others in the science of nuclear medicine. At the time this book was published Richard retired from the UK National Health Service. It is therefore fitting that Richard has contributed some excellent material within this book as this will serve as a valuable learning resource and clinical reference resource for years to come.

Foreword

Now that hybrid imaging is a well-established part of virtually all Nuclear Medicine departments, there is a great need for information on how to perform these studies to achieve optimal images. SPECT/CT is a fairly new addition to hybrid imaging and there is a paucity of information in one source, on how best to perform these studies. This book provides such a resource. This book was written to be a very practical guide to SPECT/CT imaging; consequently it is wide in scope. It provides information about both of the imaging techniques used in this hybrid system. There is detailed information about the theory and principles of imaging of gamma radiation, as well as imaging with X-rays. This is expanded to include the techniques of both SPECT and CT imaging and the imaging systems designed to acquire them in one sitting. This will be of enormous value for the vast majority of technologists and radiographers who have been primarily trained in one or the other of these modalities, but not in both. This is followed by well-illustrated clinical sections, giving examples of where this technique has been found to be useful. This includes specific recommendations of acquisition parameters, suggested injected activities and reconstruction techniques. There is also discussion of the radiation exposure resulting from these studies, including practical information on dose reduction techniques and acquisition parameters to help keep the radiation exposure a low as possible. This will be of enormous practical value as we work to keep the exposure to our patients as low as possible, while still maintaining high quality and clinical useful images. In short, this book will be a useful reference. It fills a gap in our current knowledge base in SPECT/CT imaging and should find a welcome place in every Nuclear Medicine department.

Chicago, USA Gary L. Dillehay

Preface

Around the time of installing our first SPECT/CT system in North Wales with high-powered CT, it became apparent that there was very little published work available to assist those needing information on department design, procurement, installation, testing, commissioning, and clinical implementation. Consequently, this book was conceived in the context of providing a concise reference book that would bring practical and helpful information to radiographers and technologists who are relatively new to using SPECT/CT. Reflecting on the book contents, I feel it should also be of value to trainees in radiology, nuclear medicine, and medical physics and it may also have value to those already experienced in SPECT/CT.

Contributors to the book were drawn from a wide professional base, thereby reflecting the demands and scope of SPECT/CT. When selecting contributors, I was mindful of informing them of the potential readership so that the level and range was appropriate. I also brought some authors together in order for them to write chapters or subchapters collaboratively because I recognized that together they would bring more to the text than writing in isolation. I felt that having multiple perspectives on the same topic during the writing phase would assist in the creation of a richer and more accessible reference text. With this in mind, I drew together knowledge and expertise from colleagues in North Wales, the North West of England, the South West of England, the English Midlands, and Canada, but the core text should be applicable internationally. I hope that by bringing together these gifted individuals, the initial inspiration for a practical book for radiographers and technologists has been realized and that it shall have practical value in most nuclear medicine departments, and for associated professionals.

Wrexham, North Wales, UK
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David Wyn Jones

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Abbreviations

D	Absorbed Dose
Al	Aluminum
A/C	Alternating Current
ADCs	Analog-to-Digital Converters
ALARA	As Low As Reasonably Achievable
μ	Attenuation Coefficient
AC	Attenuation Correction
ATCM	Automatic Tube Current Modulation
AEC	Automatic Exposure Control
ALMANAC	Axillary Lymphatic Mapping Against Nodal Axillary Clearance
Bq	Becquerel
BMI	Body Mass Index
E	Effective Dose
EMI	Electronic and Musical Instruments
EANM	European Association of Nuclear Medicine
CZT	Cadmium Zinc Telluride
^{11}C	Carbon-11
COR	Center of Rotation
CCTV	Closed-Circuit TeleVision
CT	Computed Tomography
CTAC	Computed Tomography Attenuation Correction
CIN	Contrast-induced Nephropathy
cps	Counts per second
CTA	Computed Tomography Angiography
CTDI	Computed Tomography Dose Index
CTF	Computed Tomography Fluoroscopy
CT#	Computed Tomography Number
CTPA	Computed Tomography Pulmonary Angiography
CCTS	Conventional Computed Tomography Scanning
DOH	Department of Health

DNA	DeoxyriboNucleic Acid
DICOM	Digital Imaging and Communications in Medicine
DVDs	Digital-Video-Disks
DC	Direct Current
DLP	Dose Length Product
ECG	Electro-Cardio-Gram
H	Equivalent Dose
FOV	Field-of-View
FBP	Filtered Back Projection
FD-CT	Flat Detector-Computed Tomography
FDG	FluDeoxyGlucose
^{18}F	Fluoride-18
FDA	Food and Drug Administration
^{153}Gd	Gadolinium-153
GEP-NETs	GastroEnteroPancreatic NeuroEndocrine Tumors
GI	GastroIntestinal
GINETs	GastroIntestinal-NeuroEndocrine Tumors
GE	General Electric
HCP	Health-Care Professional
HMPAO	HexaMethylProyleneAmine Oxime
HP-CT	High Power-Computed Tomography
HOCM	High Osmolar Contrast Media
HRCT	High Resolution Computed Tomography
HV	High-Voltage
HIS	Hospital Information Systems
HU	Hounsfield Units
HDP	Hydroxymethylene-DiphosPhonate
^{111}In	Indium-111
IAEA	International Atomic Energy Authority
ICRP	International Commission on Radiological Protection
IEC	International Electrotechnical Commission
IMRT	Intensity-Modulated RadioTherapy
ISD	InterScan Delay
IV	IntraVenous
^{131}I	Iodine-131
IR(ME)R2000	Ionising Radiation (Medical Exposure) Regulations 2000
IRR 99	Ionising Radiations Regulations 1999
IOCM	Iso-Osmolar Contrast Media
kVp	kiloVolt potential
Pb	Lead
LUTs	LookUp Tables
LEGP	Low Energy General Purpose
LEHR	Low Energy High Resolution
LEHS	Low Energy High Sensitivity
LOCM	Low Osmolar Contrast Media

LP-CT	Low Power-Computed Tomography
MRI	Magnetic Resonance Imaging
MSc NMI	Master of Science Degree in Nuclear Medicine Imaging
MAP	Maximum A Posteriori
MLEM	Maximum Likelihood Expectation-Maximization
MBq	MegaBecquerel
MIBG	Meta-Iodo-Benzyl-Guanidine
MIBI	Methoxy-IsoButyl-Isonitrile
MDP	Methylene-Diphos-Phonate
mA	milliAmpers
mAs	milliAmpere per second
mGy	milliGray
MTF	Modulation Transfer Function
^{99}Mo	Molybdenum-99
MPR	Multi-Planar Reconstruction
MSCT	Multi-Slice Computed Tomography
SVCT	Multi-Slice Virtual Computed Tomography
MPI	Myocardial Perfusion Imaging
NHS	National Health Service
NICE	National Institute for Clinical Excellence
NETs	NeuroEndocrine Tumors
NSAIDs	NonSteroidal Anti-Inflammatory Drugs
NCAT	NURBS-Based Cardiac-Torso
OJEU	Official Journal of the European Union
OSEM	Ordered Subsets Expectation-Maximization
PGD	Patient Group Direction
PACS	Picture Archiving and Communication System
PMMA	PolyMethyl MethAcrylate
PET	Positron Emission Tomography
PET/CT	Positron Emission Tomography/Computed Tomography
PET/MR	Positron Emission Tomography/Magnetic Resonance
POM	Prescription-Only Medicine
PIOPED	Prospective Investigation of Pulmonary Embolism Diagnosis
PSA	Prostate Specific Antigen
PUO	Pyrexia of Unknown Origin
QA	Quality Assurance
QC	Quality Control
RIS	Radiology Information Systems
RSNA	Radiological Society of North America
WR	Radiation Weighting Factor
ROI	Region of Interest
RCR	Royal College of Radiologists
SPR	Scan Projection Radiographs
SNR	Signal-to-Noise Ratio

SPECT/CT	Single Photon Emission Computed Tomography/Computed Tomography
SPECT/MR	Single Photon Emission Computed Tomography/Magnetic Resonance
SSCT	Single-Slice Computed Tomography
Sv	Sievert
SW	Slice Width
^{24}Na	Sodium-24
$Na^{99m}TcO_4$	Sodium Pertechnetate
SSTRs	SomatoSTatin Receptors
^{99m}Tc	Technetium-99m
^{123}Te	Tellurium-123
$^{201}T1$	Thallium-201
CsI(T1)	Thallium-activated Cesium Iodide
NaI(T1)	Thallium-activated Sodium Iodide
TLDs	ThermoLuminescent Dosimeters
3D	Three-Dimensional
W_T	Tissue Weighting Factors
2D	Two-Dimensional
USS	Ultra Sound Scan
^{235}U	Uranium-235
VIPoma	Vasoactive Intestinal Peptide tumors
V/Q	Ventilation Perfusion
VR	Virtual Reality
VRI	Virtual Reality Imaging
VDU	Visual Display Unit
WBC	White Blood Cells
WB	Whole Body
WL	Window Level
WW	Window Width
WHO	World Health Organization
^{123}Xe	Xenon-123

Part I
Scientific Principles

Chapter 1
Introduction

Peter Hogg

1.1 Introduction

This book is intended primarily for radiographers and nuclear medicine technologists who work with single photon emission computed tomography/computed tomography (SPECT/CT), but the book will be of value to other professionals within medical imaging. The intention of this book is to give a practical insight to SPECT/CT, to outline some of its uses, and also to explain how some of the more common procedures are undertaken. A fairly large amount of CT and CT-related material has been included because it is not uncommon for personnel working within nuclear medicine to have limited knowledge and experience of this modality. Purposefully we have not included a tremendous amount of information on nuclear medicine, so if the reader is novice to this field, they should consider reading a more general book about nuclear medicine alongside this text.

SPECT/CT evolved out of nuclear medicine – the addition of CT to SPECT allowed for important requirements to be offered to SPECT (attenuation correction). Serendipitously the addition of CT to SPECT also resulted in a large range of other uses for the hybrid SPECT/CT system. These additional uses did not become apparent for some years, and generally speaking, they came about through clinical and scientific staff trying out new ideas and new ways of working.

SPECT/CT evolved alongside other important advances within nuclear medicine and the broader medical imaging environment. In some respects, the progression of SPECT/CT technology and practice benefited from these advances; in other respects, it might be argued that some of these advances limited SPECT/CT's progress. Examples of advances that have likely facilitated the growth of SPECT/CT include the widespread introduction of position emission tomography (PET) and subsequently PET/CT; the broader provision of SPECT suitable radiopharmaceuticals, the

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further evolution of CT; the widespread use of picture archiving and communications systems (PACS); and the ever-increasing capacity of computers in conjunction with their ever-decreasing cost. It might be worth noting that the uptake of PET/CT, as opposed to PET without CT, came about because of the requirement for attenuation correction particularly for calculation of standard uptake values (SUVs). The technological advances made for PET/CT have no doubt advantaged the progression of SPECT/CT technology and perhaps influenced clinicians in their purchasing decisions made in relation to hybrid imaging more generally (i.e., SPECT/CT).

Today SPECT/CT has become standard in many imaging pathways, and in some circumstances, its use is written into national and international guidance. There is good reason for this; for instance, SPECT/CT can provide unique information that would be otherwise unavailable if SPECT and CT were used in isolation of each other. This unique information can assist in important decision making about patient diagnosis and management; consequently, the patient pathway and patient outcome can be altered positively.

The rationale for this book arose from discussions held with staff associated with the Diagnostic Imaging Research Programme and the Master of Science Degree in Nuclear Medicine Imaging (MSc NMI) at the University of Salford, Manchester, UK. The research program has two clinical research foci, one of which has a specific focus on an aspect of SPECT/CT, and within the MSc NMI, there is a module on hybrid imaging, which includes PET/CT and SPECT/CT. The authors of this book comprise of a professional mix that have scientific, technical, clinical, and/or theoretical knowledge of SPECT/CT. It is interesting to note that the clinical centers from which the authorship has been drawn represent the range of SPECT/CT technology which is currently on the market. This is important because this has allowed for that range of experience to be reflected into this book.

This book is divided into 5 parts and 13 chapters. Part I considers the physics and equipment which are necessary for the operation of a SPECT/CT system. Within this section, we have included information on X-rays; this addresses production and how they interact with matter. Attention is paid to X-ray production and the factors that can affect beam quality. This is important because in working practice the acquisition parameters can be manipulated in order to affect beam characteristics and ultimately CT image quality and radiation dose to the patient. As a reminder, an overview of gamma camera technology is given, and a particular emphasis is placed on the rotating camera/SPECT. As far as gamma camera construction and operation is concerned, within Chap. 3, the reader is pointed to further texts that would be necessary for a more detailed understanding. There is also a chapter dedicated to CT instrumentation and quality control. By the end of Part I, the reader should have a good grounding about the physics and technology of SPECT/CT. Part I was written by physicists and diagnostic radiographers. This professional blend was considered important, so the scope, level, and emphasis could be tailored to those professionals who would use the equipment clinically.

Part II considers practical information that should be taken into account when selecting and implementing a SPECT/CT system into a clinic. This section, written by physicists and diagnostic radiographers, draws on extensive experience from those who have written business cases for and led the installation of SPECT/CT systems. Chapter 6 elaborates upon the factors that need to be considered when choosing a system to suit the clinical work to be undertaken and client group it serves. The demands of the client group in relation to SPECT/CT equipment on the market are also taken into account. Chapter 7 gives practical advice on facility/room design for housing a SPECT/CT system. Relevant regulations are taken into account along with a host of tips and hints.

Part III addresses the medical uses of SPECT/CT by drawing on clinical information and published research. This section was written by nuclear medicine physicians and radiologists who have considerable working knowledge of SPECT/CT. This chapter contains a large number of SPECT/CT cases and images. It brings to our attention a large collection of clinical uses of SPECT/CT from routine practice. We anticipate that radiologists and nuclear medicine physicians may find this chapter to be of interest.

Part IV considers a complex issue, that of radiation protection within the hybrid SPECT/CT environment; it also considers the optimization of CT acquisition parameters with a particular emphasis on image quality. This is an important chapter for nuclear medicine managers and personnel who have limited or no experience of CT. This section was written by radiographers and a physicist.

Part V outlines a practical perspective on using SPECT/CT. This section commences with a review of cross-sectional anatomy, with a particular emphasis on surface anatomy for CT positioning purposes. We have purposefully not included physiology because generally speaking this book is primarily aimed at a NM audience, and this knowledge has been assumed to exist. Chapter 12 considers X-ray contrast media and injection systems that can be used in CT. For contrast media, complications, clinical considerations, types, and contraindications are addressed. We have included these topics because we realize that contrast media is being used for some SPECT/CT investigations; equally we acknowledge that the CT component of diagnostic quality systems is being used for stand-alone CT examinations. Finally, Chap. 13 outlines a range of common SPECT/CT procedures that can be undertaken, with suggested protocols and hints/tips for getting a successful scan. This final chapter may be of particular value to clinical centers when setting up a new service or when wishing to make modifications to existing procedures. This section was written by radiographers and nuclear medicine technologists.

1.2 Origins and Evolution of SPECT/CT

SPECT/CT comprises of two separate technologies combined into one physical unit in order to produce CT and nuclear medicine data in the same session. SPECT/CT is one of several hybrid systems currently on the market; of the hybrid installations that have already taken place, the most prevalent is PET/CT. It is worth noting that PET/MR is now commercially available, and a limited number of these systems have been installed. SPECT/MR has also been proposed, and it might be interesting to note that optical/PET and optical/SPECT are also being considered. Optical imaging is a relatively new technique which can image physiology. Triple modality hybrid systems are also being discussed.

SPECT/CT combines functional (SPECT) and anatomical (CT) imaging; the added value of CT is that a bespoke attenuation map can be generated and applied to SPECT image data to account for lost counts through self-attenuation. Aside attenuation correction, to date, another purpose of SPECT/CT has been to combine physiology and anatomy into a single registered image. Registered images are said to be of value in certain diagnostic situations; additionally, they appear to have a growing value within planning for radiotherapy. Recently, discussions within the medical imaging community have considered whether there might be value in combining two physiological imaging systems and similarly combining two anatomical imaging systems [1]. Publications are starting to emerge to speculate the value of PET and SPECT combined with optical imaging. It is worth noting that the integration of MR with PET or SPECT has been slow to move forward, and various factors have accounted for this. For instance, MR is unable to provide data for attenuation correction, unlike CT; also there continues to be inherent problems of enabling MR to work easily alongside PET or SPECT, and vice versa. Each machine has the potential to interfere with the successful running of the other.

Although the concept of SPECT/CT was reported over two decades ago [2], it is only in recent years that these hybrid systems have gained widespread popularity and use in the clinical routine. The initial intention for having an integral SPECT/CT system was for attenuation correction of SPECT data; in this respect, the CT unit represented an important advancement from the radioisotope and/or mathematically based alternatives. Gd-153 is an example of a radioisotope external beam method for empirically deriving a bespoke attenuation map for SPECT data. Limitations of the radionuclide approach surrounded the low radiation output when the Gd-153 became older (through physical decay) and also the cost of replacing the Gd-153 sources. An alternative to the radionuclide approach was mathematical modeling. Modeling made assumptions about body composition, and when the assumptions were not met the attenuation correction data could be highly inaccurate. For instance, one approach assumed that all pixel values would be the same and when values varied significantly large attenuation correction errors would be incurred. One body area where this approach had limitations was the chest; by contrast, the brain is fairly homogenous and less prone to such errors.

Moving to the hybrid SPECT/CT environment comprised of two major stages, the first did not involve the physical fusing of the two technologies while the second did. In the first stage, image data from CT and SPECT were acquired on machines that were situated in physically different locations. The two datasets were then brought together and registered to enable CT attenuation maps to be applied to SPECT and/or images to be fused for display. This approach was fraught with problems, including difficulties in aligning datasets from different machines and the potential for poor scheduling between the two scans – in some instances, the SPECT and CT images could be generated days or even weeks apart. Such time differences could render the datasets difficult to compare, not least because the pathology could have progressed and/or spread; consequently, the CT and SPECT data would be reflecting a real difference that could not be correlated/registered.

The first commercially produced SPECT/CT system was introduced by General Electric in 1999. The CT component comprised of low-dose fixed output with a maximum tube current of 2.5 mA. In some respects, this initial commercial response to the SPECT/CT market was relatively easy to introduce into the clinical routine. Aside the complexities of X-ray radiation protection, the operation of the CT component was quite easy, as it had preset values with one intention in mind (attenuation correction). As experience with fixed output systems grew, clinical staff experimented with the low-quality CT images that were produced, and it started to become apparent that these images may have clinical value. In the first instance, their value surrounded assisting with the anatomical location of hot or cold areas seen on SPECT. However, the limitations of the fixed output CT machine's image quality meant that its clinical value was restricted.

Since the early days of limited image quality, the CT component of the SPECT hybrid system has evolved considerably, and today systems offer multislice potential of equal ability to stand-alone diagnostic CT machines. Sitting between the high-end diagnostic quality and fixed output CT systems are a number of midrange machines. These midrange CT machines offer limited acquisition flexibility. For instance, there may be the option to select from a limited range of mA and kVp values; these parameters can affect image quality. Figure 1.1 illustrates three CT slices taken of the same anthropomorphic chest phantom. The displayed slices are at approximately the same level. Image A is from a fixed output single slice CT machine, image B is from a midrange 4 slice CT machine (using 2.5 mA), and image C is from a diagnostic quality CT machine (16 slice). On comparing the three slices, it is clear that resolution differences are evident. It is worth noting that the anthropomorphic phantom is stationary during CT image formation, in a human because of long exposure times, there could also be blurring due to breathing and heart motion.

In the early years of SPECT/CT, debates were held on whether this hybrid technology might be a passing fashion simply because its initial intention was limited to the attenuation correction of SPECT data and that application was restricted to certain procedures and often on specific patient populations therein. Some considered SPECT/CT to be a very expensive solution to attenuation correction, assuming that this was its sole purpose. Not surprisingly, questions were raised about value for money. However, the move toward midrange and diagnostic quality CT scanners opened up new possibilities which were capitalized on within business cases and working practice. For instance, the high-end diagnostic quality CT scanner could be operated as stand-alone; consequently, if required, it could provide an alternative service to the main X-ray department CT scanner. This would have value for imaging patients when the main CT unit was unavailable (e.g., during servicing and breakdown); also it could provide additional CT capacity when required. It may be worth noting that the provision of additional capacity has been adopted by some centers, as they now run CT sessions in certain evenings of the week after the radioisotope scanning has finished for the day. Business cases have been made for

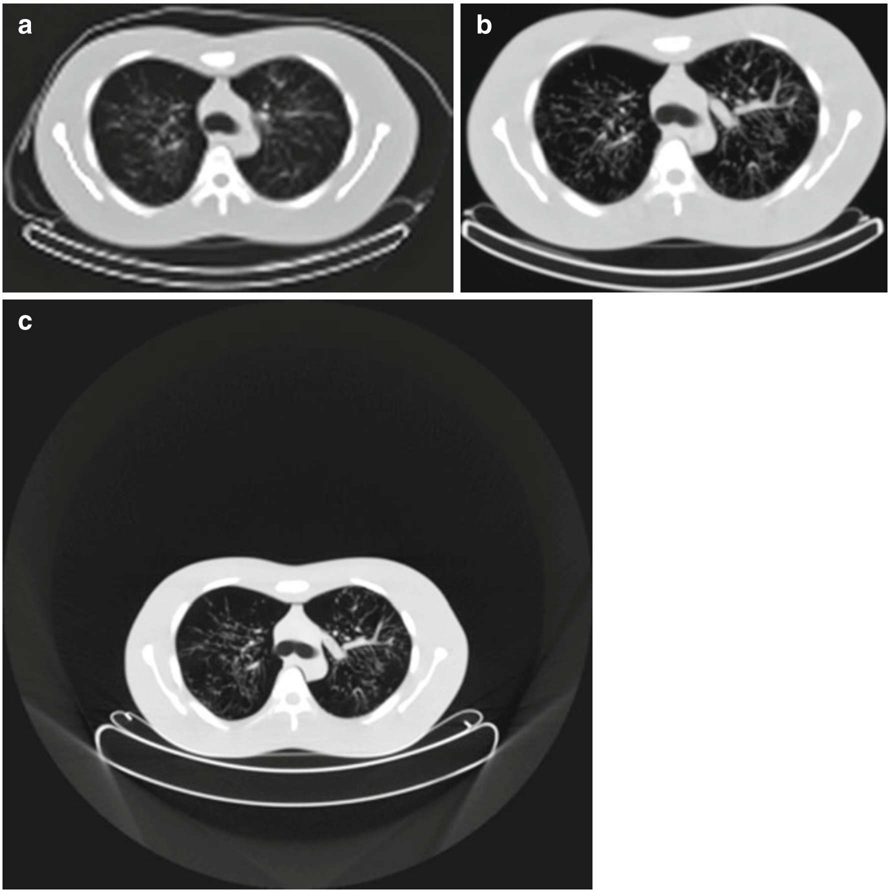

Fig. 1.1 (**a**) Low-resolution/fixed output. (**b**) Medium resolution. (**c**) High-resolution/diagnostic quality

SPECT/CT systems on this basis, and for a radiology department, it might be more cost-effective to install a high-end diagnostic quality SPECT/CT system than purchase an additional stand-alone CT system and a lower-end SPECT/CT system as well. This decision would of course be influenced by CT workflow.

Having integral diagnostic quality CT with SPECT has resulted in new possibilities for imaging and patient workflow. For instance, diagnosis of some conditions which previously may have required multiple patient visits for imaging using the different modalities can now be consolidated into one hospital visit. This has particular benefits to patients in that one hospital visit, rather than two or three, would be required. This approach reduces travel costs to the patient, and if they were quite unwell, then the stress and effort of having many hospital visits would be reduced too. Depending upon the patient and their condition, this could mean hospital savings too, for instance, ambulance transport may be required on one rather than several occasions. However, this condensed approach has brought new patient related problems which do require consideration, for instance, the patient may find out much more quickly what is wrong with them where previously it could take several days for the information to be revealed, thereby allowing the patient a chance to acclimatize to any unwelcome and stress-inducing news.

Until the introduction of SPECT/CT, the only alternative way into the hybrid market for a radiology department was PET/CT. PET/CT scanners remain more expensive than SPECT/CT systems, this being especially true when the cost of the ancillary equipment and consumables (e.g., cyclotron and the cost of the PET radiopharmaceutical) are taken into account. Being cheaper, SPECT/CT allowed for a radiology department to enter the hybrid imaging market at a fraction of the price of PET/CT. Today, when replacing a gamma camera, it is common that consideration is given to whether a SPECT/CT system should be installed as the gamma camera replacement. Various factors come to play when making this decision, including the available finance and the clinical work that will be conducted on it. SPECT/CT has particular values, as will be highlighted in this book, and the case for purchasing a system should take these into account. Of course replacing a gamma camera with a SPECT/CT system comes with hidden costs, and these should not be overlooked. For instance, there will be a requirement to install secondary radiation shielding into the room walls and doors. Also there may be a need to provide a shielded area within the imaging room for the imaging staff, or more commonly provide a shielded control room from which the patient can be observed through lead glass and/or CCTV.

Unlike PET/CT, SPECT/CT had a surprising start to its emergence into the clinical routine. By early 2008, in spite of there being a growing number of SPECT/CT installations, the literature was highly deficient with fewer than 150 journal publications being available worldwide. Of these, many were speculative; empirical pieces did exist, but many had very small patient numbers. Around that time, the notion of evidence-based practice for SPECT/CT was clearly not possible, which on reflection is quite concerning. This was recognized as a problem within the European Association of Nuclear Medicine conference in 2008. Various explanations have been put forward since 2008 about the literary deficiency around that time with one of the more plausible being that eminent national and international scientists had focused their energies into PET/CT, rather than SPECT/CT, perhaps because of PET/CT's acknowledged value in many aspects of current and future medical practices. Today the picture is brighter because much more SPECT/CT literature has been published into journals, and a growing number of books/book chapters dedicated to SPECT/CT have started to appear. It might be worthwhile remembering that quality literature is important to the evolution of medical techniques and medical devices, and this obviously includes SPECT/CT. Health-care systems in various countries have adopted the philosophy of evidence-based practice. Ideally evidence should be generated prior to the widespread introduction of a new technique, as this protects the patient from harm and inappropriate practice. Also it protects the employer and health-care team from clinical negligence claims which can arise from inappropriate care and management.

1.3 The Virtues and Challenges of Change

Depending upon how imaging services are resourced and managed, it is possible that the fusion of SPECT and CT would bring together different cultures and different disciplines. For instance, nuclear medicine (SPECT) personnel may have to integrate and work closely with radiology (CT) personnel. Philosophically speaking, this union can bring tremendous opportunity. For instance, the sharing of different perspectives, experience, and ideas can present a powerful catalyst for innovation and advancement; indeed such innovation and advancement are evident in practice and in the SPECT/CT literature.

On a practical level, the fusion of different cultures and practices can present challenges, and these need to be acknowledged and, as required, resolved in an amicable fashion. For example, radiographers and radiologists who practice nuclear medicine are likely to be able to perform/interpret CT examinations; for nuclear medicine technologists and nuclear medicine physicians, they may need to develop CT skills. Similarly, the technical teams that support the equipment, including physicists and technicians, may also have specific backgrounds and therefore be specialist in only one of the two technological areas. In itself, the knowledge and skill differences must be seen as relatively minor problems as appropriate education and training can be sought to redress any perceived deficiencies. Admittedly there may be conflicts in role definition between professional groups which will likely require clarification and resolution. Such political negotiations can be time consuming and stressful as they will no doubt take into account emotional responses which have good grounds from a personal perspective, but they do not necessarily have good grounds from a service delivery and patient standpoint.

There is a very good example of two professional groups coming together to agree practice standards in hybrid imaging. While the field is PET/CT, the principle would be the same as SPECT/CT. In 2004, with an emphasis on PET/CT, America addressed a competence and practice imbalance. The American Society of Radiologic Technologists together with Society of Nuclear Medicine Technologist Section produced valuable documentation on the knowledge and skills required to operate a hybrid system, to include CT [3]. The proposal was that multiple pathways should be created to train professionals, the multiple pathways being necessary because of the different routes people may take into hybrid imaging (e.g., from nuclear medicine or from radiography/radiology). Subsequent to this scientific and professional bodies in other countries have responded similarly with proposals on what skills and knowledge may be required for working in a hybrid environment [4].

Training/competence is only part of the solution to overcoming change challenges. In some countries, regulatory (legal) restrictions on “who can do what” may inhibit nuclear medicine technologists and others from making CT exposures. Considering this matter from a patient-centered stance, the emphasis should be on competence to practice, because it should be a matter of patient safety and well-being rather than a professionally focused argument which asserts that only certain professional groups can do the task/assume the responsibility. Expanding the