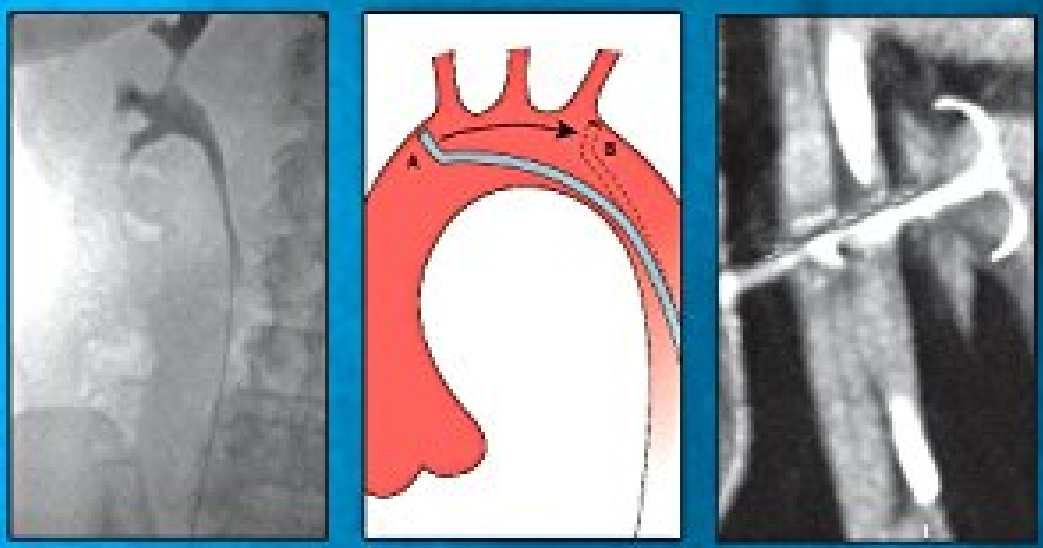
David Kessel
Iain Robertson



INTERVENTIONAL RADIOLOGY

A SURVIVAL GUIDE

ELSEVIER

Fourth Edition

INTERVENTIONAL RADIOLOGY

INTERVENTIONAL RADIOLOGY

A SURVIVAL GUIDE

Fourth Edition

David Kessel MB BS MA MRCP FRCR EBIR
Formerly Honorary Clinical Associate Professor
University of Leeds
Leeds, UK

Iain Robertson MB ChB MRCP FRCR
Consultant Radiologist
Gartnavel General Hospital
Glasgow, UK

With a contribution by:
Des Alcorn, MBCHB, FRCS (Glasgow), FRCR
Consultant Radiologist
Department of Radiology
Gartnavel General Hospital
Glasgow, UK

ELSEVIER

ELSEVIER

First edition 2000
Second edition 2005
Third edition 2011

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

With respect to any drug or pharmaceutical products identified, readers are advised to check the most current information provided (i) on procedures featured or (ii) by the manufacturer of each product to be administered, to verify the recommended dose or formula, the method and duration of administration, and contraindications. It is the responsibility of practitioners, relying on their own experience and knowledge of their patients, to make diagnoses, to determine dosages and the best treatment for each individual patient, and to take all appropriate safety precautions.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-0-7020-6730-3
E-ISBN: 978-0-7020-6888-1

Executive Content Strategist: Michael Houston
Content Development Specialist: Joanne Scott
Senior Project Manager: Beula Christopher
Senior Designer: Miles Hitchen
Illustration Manager: Karen Giacomucci
Illustrator: Marie Dean
Marketing Manager: Rachael Pignotti

Printed in China
Last digit is the print number: 9 8 7 6 5 4 3 2 1

Preface

Writing books is a lot like many of the practical tasks in Interventional Radiology. After the rush of excitement for the first few attempts you might be slightly less enthusiastic next time but you sure are a lot more experienced in what works and what doesn't! This is our fourth edition of *Interventional Radiology: A Survival Guide* and we are starting to get the hang of it (both writing books and Interventional Radiology).

Our aim remains for this to be the 'go to' book for the practical techniques of Interventional Radiology, written in a friendly, if sometimes slightly sardonic, style. (We each blame the other for that sardonic bit creeping in.) We share your pain. We have learned the lessons of successful procedures either by watching them unravel at our own hands or even worse, trying to retrieve a procedure which someone else has unravelled for you. The experience in this book cannot replace having a friendly experienced colleague standing nearby and cheering you on but we try to get as close as possible.

The way we interact with knowledge has changed. When we started the survival guide, all our attention spans were so much longer that readers actually started books from the front and, reasonably, often read all the way to the end. Can you imagine that? Now we all tend to dip in and out of knowledge sources – it's a miracle you've read this far in the preface alone!

To reflect these changes, the book has undergone a major rewrite, making it much more accessible and easier to dip in and out of. We have improved the format to include sections on essential equipment, and a principles section, which provide the foundations of Interventional Radiology. Many of the sections have been expanded to reflect the growth in Interventional Radiology. In particular, we have included much more on Interventional Oncology and we are hugely indebted to Dr Des Alcorn for his help and guidance with the sections on tumour ablation.

As always, we feel that having finished writing the fourth edition of the survival guide, we now understand much more about Interventional Radiology and hope that you will feel the same after reading it.

Abbreviations

AAA	abdominal aortic aneurysm
AV	atrioventricular
CCA	common carotid artery
CCF	congestive cardiac failure
CECT	contrast-enhanced computed tomography
CE-MRA	contrast-enhanced MRA
CFA	common femoral artery
CFV	common femoral vein
CIA	common iliac artery
CTA	computed tomography angiography
CVA	cerebrovascular accident
DSA	digital subtraction angiography
DVT	deep vein thrombosis
EIA	external iliac artery
ERCP	endoscopic retrograde cholangiopancreatography
EVAR	endovascular aneurysm repair
FBC	full blood count
FFP	fresh frozen plasma
FNA	fine-needle aspiration
FNAC	fine-needle aspiration cytology
fps	frames per second
GTN	glyceryl trinitrate
IADSA	intra-arterial digital subtraction angiography
IJV	internal jugular vein
IM	intramuscular
IMA	inferior mesenteric artery
IV	intravenous
IVC	inferior vena cava
LAO	left anterior oblique
LGA	left gastric artery
MIP	maximum intensity projection
MPDSA	multiposition DSA
MRA	magnetic resonance angiography
MRI	magnetic resonance imaging
NSAID	non-steroidal anti-inflammatory drug
PA	popliteal artery
PE	pulmonary embolism
PFA	profunda femoris artery
PIG	peroral image-guided gastrostomy
PTC	percutaneous transhepatic cholangiography
PVA	polyvinyl alcohol
RAO	right anterior oblique
RAS	renal artery stenosis
RHV	right hepatic vein
RIG	radiologically inserted gastrostomy
RIJV	right internal jugular vein
RPV	right portal vein
rt-PA	recombinant tissue plasminogen activator
RVEDP	right ventricular end-diastolic pressure
SFA	superficial femoral artery
STD	sodium tetradecyl sulphate
SVCO	superior vena cava obstruction
SVT	supraventricular tachycardia
TIPS	transjugular intrahepatic portosystemic shunt
TJB	transjugular liver biopsy
TN	tibial nerve
TOS	thoracic outlet syndrome

1

Planning safe procedures

Making the correct treatment plan

This chapter focuses on steps you should take to minimize risk and prepare yourself and the patient for successful and safe procedures. You may be tempted to skip past to get to the action and give this section little more than a perfunctory glance. Do so at your own peril, every patient has the right to expect that they will receive timely and correct treatment and that an appropriately skilled practitioner will perform their procedure. The adage '**Proper Planning Prevents Poor Performance**' applies in interventional radiology and heeding it will help you maximize your chances of achieving a successful outcome for the patient. Before rushing off, needle in hand, stop and ask yourself the following questions:

- Does the patient really need/want an intervention?
- Have you and the patient considered and understood the pros and cons of the alternative treatment options?
- Is the proposed procedure the most appropriate in the clinical situation?
- Does the patient understand what is in store and the potential risks and benefits?
- Do you and the patient have similar and realistic expectations for the outcome?
- Are you and the team prepared for all eventualities?

If you are unsure or have answered no, then seek advice and make sure that you document your discussions with colleagues and the patient. It is always better and safer to delay or cancel a procedure than to rush headlong into the wrong option.

Preparing for successful and safe procedures

There are three distinct aspects to consider when preparing for procedures, these relate to:

- The patient
- The team who will perform the procedure
- The environment before, during and after the procedure, including recovery and destination ward.

These must be addressed in advance of every procedure in the outpatient department, at multidisciplinary team meetings, on the ward, in discussion with clinicians and members of the radiology team. The amount of planning will vary with the complexity of the procedure and the needs of the individual patient but clear documentation is mandatory at each stage.

Patient preparation

The key elements required to ensure that patients are properly prepared for a procedure are **evaluation** and **information.** Each assumes that you understand the procedure yourself.

Evaluation

The focus of evaluation is the identification of factors which may increase the risk of the procedure. Complex procedures should be discussed at multidisciplinary team meetings where all the different therapeutic options can be considered.

Screening tests Routine investigation (blood testing and electrocardiogram [ECG]) of all patients is unnecessary and merely increases the cost of patient care. In deciding whom to screen, consider the 'invasiveness' of the planned procedure and the likelihood of detecting an abnormality which would affect patient management. There is little evidence on which to base management, except in the case of prevention of contrast-induced nephropathy. The guidelines below are suggestions for screening and are not absolute; if in doubt, it is better to perform a non-invasive test.

Evaluation of renal function is indicated when the patient:

- Has a history of renal dysfunction
- Has a disease likely to impair renal function, e.g. hypertension, especially with peripheral vascular disease
- Is diabetic and has not had recent evaluation of renal function
- Has heart failure
- Is receiving nephrotoxic drugs.

Clotting studies are indicated when the patient:

- Has clinical evidence of a coagulopathy
- Has a disease likely to affect clotting, e.g. liver disease; therefore, it is unwise to perform a liver biopsy without knowing the coagulation status
- Is receiving medication that affects coagulation, e.g. heparin, warfarin or other anticoagulant or antiplatelet agents.

Platelet count is indicated in conditions that affect blood cell production or consumption, e.g. leukaemia, hypersplenism and cancer chemotherapy.

- Full blood count (FBC) is obtained in the context of bleeding but is less important than physiological status.

Alarm: Remember numbers may be misleading, e.g.:

- Haemoglobin can be normal for several hours after acute haemorrhage.
- Platelet number may be normal but function may be abnormal, particularly in patients on dual antiplatelet agents.

ECG is indicated when the patient:

- Has a history of cardiac disease
- Is to undergo a procedure likely to affect cardiac output or cause arrhythmia, e.g. cardiac catheterization.

Information

In order to decide whether to undergo treatment, patients need a basic understanding of their condition and how likely the proposed intervention is to alleviate symptoms or improve

prognosis. They also need to understand the therapeutic alternatives and the relative risks and benefits of each approach to managing their condition. Expect patients to have researched their condition on the internet; your job is to help them to make sense of the bewildering mixture of fact and fiction they have found. For all but the most basic procedures it is best to see the patient in advance, either on the ward or in an outpatient clinic.

Be straightforward and honest about your ability and experience and do not be afraid to allow a patient the opportunity to seek a second opinion. Patients will respect this and it is the least you would expect from someone treating you.

Informed consent Patients have a right to be given sufficient information to make informed decisions about the 'investigation/treatment' (these terms will be used synonymously) options available to them. Your role is to provide relevant information in a way that they can comprehend. The laws regarding informed consent vary from country to country; these guidelines are based on the current situation in the UK but the ethos is broadly applicable.

Recent case law in the UK has changed the focus of consent to consider what the 'prudent patient' would be likely to want to know. This means that patients should be warned of 'material risks' associated with a procedure, even if they are uncommon. For instance, acute limb ischaemia is a recognized complication of peripheral arterial angioplasty; this may require surgery to restore flow and could conceivably lead to amputation or even result in death. Although uncommon, these risks must be mentioned and the likelihood of these events occurring must be put into perspective. In the UK at least, this has significant ramifications for consent.

Material risk In practical terms, a 'material risk' is anything that a 'reasonable person' in the patient's position would be likely to consider important. This includes the common and serious side-effects (and their management) of the proposed procedure. It also encompasses anything that the doctor would presume to be important to the individual patient. For instance, ischaemia of a fingertip would be expected to have particular relevance to a concert pianist, as it would potentially result in a loss of livelihood.

Alarm: When considering 'material risk' ask yourself what you would want to know before agreeing to treatment. You should comment when the treatment is complex, unfamiliar or involves significant risk for the patient's health, employment, or social or personal life. Document the key elements of any explanation and record any other wishes that the patient has in relation to the proposed treatment.

Consent issues A qualified doctor who understands the risks and side-effects of the procedure should be responsible for obtaining consent for treatment. Usually the doctor performing the treatment is in the best position to provide this information. If this is not practicable, the doctor may delegate to an appropriately experienced colleague. You must provide a balanced explanation of the treatment and alternative management options along with the risks and benefits of each. Include things a prudent patient might want to know, such as:

- The general nature and purpose of the proposed treatment, including analgesia, sedation and aftercare
- Are there alternative therapeutic options? This might include doing nothing, optimizing medical therapy, surgery or other interventional approaches
- Information about those performing the procedure including:
  - The name of the doctor with overall responsibility for the patient
  - Names of the relevant members of the doctor's team, e.g. anaesthetist and surgeon
  - The experience of the operator/team with the procedure.
- What are the 'material risks' of the procedure and how common are they?

- Realistic expectations of the outcomes of the procedure, e.g.
  - What is the likelihood of the procedure being a technical success?
  - Will this have the clinically desired effect?
  - Is the treatment a cure?
  - What is the likelihood of recurrence?
- Will this treatment strategy impact on their future management?

The form of the explanation and the amount of information provided vary depending on the patient's wishes, their capacity to understand and the nature and complexity of the treatment. The patient should be allowed time to consider the information and must not be pressurized to make a decision. The patient must be told that they can change their mind or seek a second opinion at any time without prejudicing the care.

Review the patient's decision close to the time of treatment. This is mandatory when:

- Significant time has elapsed since consent was obtained. Many consent forms have a section to allow reaffirmation of consent.
- There have been changes that may affect the treatment strategy or outcomes.
- Someone else has obtained consent.

Alarm: Compliance is not the same as consent! The patient's presence in the interventional suite does not indicate that the patient knows what the treatment entails. Documenting and checking the consent avoids misunderstanding and is the best defence in the event of litigation.

Special circumstances There are instances in which it is difficult or impossible to obtain informed consent. There are some general guidelines for what is acceptable procedure. If there is any doubt, legal advice should be obtained either from the hospital administration department or your medical indemnity provider.

Emergencies When consent cannot be obtained, you may only provide whatever medical treatment is necessary to save life or prevent significant deterioration in the patient's condition.

Capacity to make decisions This is the ability to understand and retain information for long enough to evaluate it and make a decision.

Inability to comprehend Seemingly irrational decisions and refusal of treatment are not evidence of a lack of capacity. Take time and review whether the patient has been provided with sufficient information or has not fully understood any of the explanation. Where doubt exists, seek advice; there is guidance for the formal assessment of capacity.

Fluctuating capacity When the patient's mental state varies and the decision can wait, consent should be obtained during periods of lucidity. This should be reviewed at intervals and recorded in the patient's notes.

In the UK, no one can give or withhold consent of treatment on behalf of a mentally incapacitated patient unless they have been legally authorized to do so. Try to establish whether the patient has previously indicated a preference, e.g. in an advance decision. If the patient complies, you may carry out any treatment that is judged to be in the patient's best interest. In these circumstances, it is prudent to seek a second opinion and for this to be documented in the patient record.

Children At the age of 16, the patient should be treated as an adult. Children below the age of 16 who are able to understand the nature, purpose and consequence of the procedure or its refusal have the capacity to make decisions regarding their treatment. In England, if a competent child refuses treatment, a person with parental authority or a court may give

consent for any treatment in the child's best interest. Seek legal advice when doubt exists. A person with parental authority may authorize or refuse treatment for a child who is not competent to give consent. You are not bound by parental refusal; seek legal advice. In an emergency, proceed as above.

Managing high-risk patients

The role of interventional therapy is extending to some of the highest-risk patients, such as those with major bleeding from the gastrointestinal tract and secondary to trauma.

Risk management begins in advance of the procedure and starts by identifying which patients are at higher risk from the intervention (e.g. bleeding diathesis, allergy to contrast) and also whether they pose a risk to staff (e.g. infection control). It will also identify specific challenges such as the need for a hoist for a very heavy patient or a translator in case the patient speaks a different language.

In some cases, risk is evident from the nature of the procedure being undertaken. In other cases, it is necessary to seek out the relevant information from the patient, the referring clinicians or staff on the ward.

Most units will perform some form of screening for risk at the time of booking a procedure using a standard series of questions or proforma. This will identify the majority of the known conditions and risk factors. In addition to this, further checks should be performed once the patient is admitted to the hospital or day-case unit. This allows an additional opportunity to provide instructions for ward staff and the patient (e.g. the need for intravenous cannulation). If you use each of these opportunities and pay attention to detail few patients will cause surprises when they arrive for the procedure and your lists are more likely to go according to plan.

Having identified patients who are at increased risk, it is necessary to have strategies to manage them. Consider the risk in the context of the patient's condition. Clearly, there is a balance of risk; the risks of the procedure should be minimized, but the patient's wellbeing is paramount. You may be advised that 'the patient is too unstable to bring to radiology' but, for a patient with life-threatening haemorrhage, the time to stopping bleeding is key and there is seldom logic in delaying a potentially life-saving procedure! This section aims to help you keep the risk to the patient and to yourself as small as possible.

This list is not comprehensive, so pause to consider before every individual case and never hesitate to seek advice.

The patient's general condition

American Society of Anesthesiologists (ASA) status classification system

Anaesthetists will often quote ASA scores to you (see: http://www.asahq.org/resources/clinical-information/asa-physical-status-classification-system). The grading allows a common understanding of a patient's pre-procedure physical condition. The ASA score should not be used for prognostic indication, as actual risk will be affected by other factors such as age, body mass index, type of procedure, anaesthetic technique and operator experience.

In practice you need assistance with ASA IV patients (life-threatening condition), and ASA V (will not survive without intervention) patients require immediate attention!

The patient has a history of anaphylactic reaction to intravascular contrast This is fully discussed in Chapter 3. Consider alternative imaging strategies such as duplex ultrasound and magnetic resonance angiography (MRA), or another contrast agent such as gadolinium or carbon dioxide (CO_2).

The patient is anticoagulated or has a severe bleeding diathesis. The risk relates to the nature of the procedure; simple drainage and venous puncture are safer than arterial puncture or core biopsy. The risk of haematoma following angiography increases when the platelet count is 100×10^9/L. For surgery and invasive procedures, the platelet count should be $\geq 50 \times 10^9$/L.

Evaluate each case on its own clinical merit, consider postponing elective procedures to allow investigation and correction of the coagulopathy. Only intervene to correct the clotting if the procedure is urgent.

Tip: Abnormal clotting is relevant mainly when the time comes to obtain haemostasis. Consider using a closure device (Ch. 37). Alternatively, leave a sheath in the artery until the clotting is corrected. An arterial line may be helpful for patients in the intensive therapy unit.

Diabetes Diabetic patients are at particular risk because of:

- The protean manifestations of diabetes, especially cardiovascular and renal disease
- Potential problems with diabetic control in the peri-procedural period.

Non-insulin-dependent diabetic patients The risks of lactic acidosis in patients taking metformin appear to have been exaggerated. The current UK recommendation from the Royal College of Radiologists (https://www.rcr.ac.uk/sites/default/files/Intravasc_contrast_web.pdf) has recently been revised. Guidance now states that renal function should be known; if the creatinine is normal or the estimated glomerular filtration rate (e-GFR) is >60 mL/min per 1.73 m^2 then metformin can be continued. If the creatinine is elevated or the e-GFR is <60 mL/min per 1.73 m^2 then the decision to continue or stop metformin for 48 h following contrast should be taken in conjunction with the referring team. Stopping metformin is not without risk and some patients will need to take insulin to control their diabetes over this period. In general, metformin should not be restarted until stable renal function has been confirmed 48 h after the procedure.

Insulin-dependent diabetic patients There are various regimens in practice and your hospital will have its preferred strategy. The following are simple principles that can be applied to most insulin-dependent diabetic patients:

- Avoid prolonged fasting
- If possible, schedule their procedure early in the morning. In this case they should take their long-acting insulin as usual but omit the short-acting insulin.
- If the procedure is later in the day, leave out the short-acting insulin and halve the dose of the long-acting insulin.
- A 5% dextrose solution should be infused to provide 5–10 g/h of glucose; this will usually maintain the blood glucose in the range 6–11 mmol/L.

Tip: Ask the patient if they recognize when they are becoming hypoglycaemic. If they do, tell them to advise you if they develop symptoms. If not, then check the blood sugar periodically during the procedure.

Alarm: Hypoglycaemia is more important than transient hyperglycaemia. Sweating, confusion and anxiety can all indicate significant hypoglycaemia. It is seldom unsafe to give the patient dextrose.

Renal impairment Chronic kidney disease (CKD) is common in very sick patients, the elderly and those with peripheral vascular disease. Roughly 50% of renal function has been lost by the time the creatinine rises above the normal limit. Estimated glomerular filtration

rate (eGFR) is a better indicator of renal function. If the creatinine is elevated or the eGFR is <60 mL/min per 1.73 m^2 renal function is abnormal. Patients with CKD are at particular risk of developing contrast-induced acute kidney injury (CI-AKI). This is defined as a rise in an absolute rise creatinine of 0.3 mg/dL or 26 µmol/L or a 1.5 × increase within 48 h. In practice, if the patient is under 70 years old with no history of cardiovascular disease or renal dysfunction, the risk will be low, but ideally the e-GFR should be known for all patients undergoing elective procedures. Although few patients will require dialysis as a result of CI-AKI, prevention is better than cure. **The most important factor in protecting renal function is ensuring adequate hydration using normal saline.** If intravascular iodinated contrast is essential then non-ionic isosmolar agents probably minimize the risk. There is no evidence that any other pharmacological regimens reduce the incidence of contrast-induced acute kidney injury.

Alarm: eGFR is calculated using data including age, race and sex of the patient. If your laboratory does not provide eGFR reports, you can calculate it using online calculators (e.g. http://egfrcalc.renal.org).

1. **Is this the most appropriate investigation?** Consider using alternative tests (MRA, Doppler, CO_2). Remember that there is a risk of nephrogenic systemic sclerosis in patients given gadolinium-based contrast for magnetic resonance imaging (MRI) and non-contrast techniques should be considered, especially for angiography.
2. **Review medication. If possible consider stopping:**
   - Non-steroidal anti-inflammatory drugs (NSAIDs)
   - Angiotensin-converting enzyme inhibitors (ACE-Is) and angiotensin II receptor blockers unless there is severe heart failure
   - Metformin (stop for 48 h and restart if creatinine stable).

   Avoid loop diuretics if possible.
3. Act according to the severity of the CKD (based on e-GFR) and involve a nephrologist early:
   - Stage 1 and 2 **CKD, minimal risk e-GFR >60 (Cr <120)**
     Ensure hydration Oral fluids 1 L pre- and post-procedure
   - Stage 3a and 3b, **low risk e-GFR 30–59 (Cr 120–180)**
     Inpatient: Non-ionic contrast, IV normal saline 1 mL/kg per hour, 12 h pre- and post-procedure
     Outpatient: Iso-osmolar contrast (iodixanol). Encourage oral fluids 1 L pre- and post-procedure, if possible IV normal saline started on arrival 1 L over 4 h.
   - Stage 4, **intermediate risk e-GFR <30 (Cr >180 or renal transplant)**
     If possible admit for procedure: iso-osmolar contrast IV normal saline 1 mL/kg per h (caution if congestive cardiac failure [CCF]) 12 h pre- and post-procedure *N*-acetylcysteine 600 mg PO (two doses pre- and post-procedure).
   - Stage 5, **high risk, CrCl <15**
     Admit for procedure; as above. Repeat Cr at 7 days.
   - **Avoid further contrast exposure for 72 h if possible.**
4. Other risk factors, e.g. diabetes mellitus, multiple myeloma, CCF, cirrhosis: consider promoting to the next level of CKD.

Tip: Hydration – in the presence of CCF or cirrhosis with ascites, use 5% dextrose instead of saline.

Hypertension Hypertension is common and is exacerbated by anxiety and pain. Hypertension increases the risk of haematoma. Review the ward charts to check the normal

baseline blood pressure (BP). The Society of Cardiovascular and Interventional Radiology (SCVIR) standards define uncontrolled hypertension as a diastolic pressure >100 mmHg. Systolic hypertension is present when the systolic pressure is >180 mmHg.

Controlling high blood pressure starts on the ward. The patient should take any antihypertensive medication (except loop diuretics) as normal. If they remain hypertensive in the angiography suite, they can be given 10 mg of nifedipine. Sedation and analgesia may also help blood pressure control. Aim to reduce the mean blood pressure by no more than 25%.

Tip: If the blood pressure cannot be controlled by these simple measures, postpone elective cases until the patient is appropriately medicated on the ward.

Heart failure The patient's condition should be optimized before angiography. Diuretics should be avoided if possible to minimize the risk of nephrotoxicity. Limit the study to the essential details. If necessary, breathless patients can often sit up slightly; this can be compensated for by craniocaudal angulation of the C-arm. Give oxygen as necessary.

Gastric contents It is normal to fast patients before invasive procedures but the risk of aspiration of gastric contents is very small except in sedated patients. General guidelines are shown in Table 1.1. These are mandatory before conscious sedation or anaesthesia and advisable before other cases.

Table 1.1 General guidelines for fasting time before invasive procedures

Oral intake	Fasting time (h)
Solids and non-clear liquids	6–8
Clear liquids	2–3

In urgent cases, seek anaesthetic advice, avoid sedation and consider metoclopramide to promote gastric emptying, H_2 antagonists or proton pump inhibitors to increase gastric pH and antiemetics to minimize the risk of vomiting.

Patients with dementia, anxiety and agitation It is not safe to embark on an invasive procedure in a patient who cannot cooperate due to significant confusion or agitation. These patients may require sedation or general anaesthesia to allow the procedure to be performed successfully. Patients with anxiety will respond to sedation, those with dementia rarely do and in this case, general anaesthesia is usually the safest option for both the patient and staff. Consent issues are also relevant in this group of patients (see above).

2

Pre-procedure safety check

Formal and clearly documented safety checks and briefings are mandatory and essential if you want to reduce predictable and preventable errors during procedures. It has been clearly demonstrated that safety checks performed immediately before and after every surgical operation reduce patient morbidity regardless of the environment. The surgical safety checklist has been adopted worldwide and similar checks should be used in interventional radiology.

This chapter builds on the ethos of the surgical safety check and suggests reviewing complex elective cases in advance of the day of the procedure in addition to further formal reviews at the start and end of every day.

Advance planning

There are two separate aspects to advance planning: administrative and personal preparation.

Administrative preparation

This is usually the role of the radiographic or nursing staff. There should be a screening process aimed at identifying risk factors such as anticoagulation in advance of the procedure. The aim of this process is to avoid surprises on the day and thus prevent delays or cancellation. Screening is often carried out through a telephone checklist review with the patient or with their source ward. Once risk factors are identified, appropriate planning and mitigation should take place, e.g. converting a patient on warfarin to heparin or scheduling diabetic patients first on the list.

Personal preparation

It is always worth reviewing the imaging and mentally rehearsing the procedure. This is particularly true of more complex interventions and is mandatory for cases that require equipment which is not routinely stocked. This one habit prevents a lot of delay and disappointment and pre-rehearsal generates the opportunity to discuss cases where there is any uncertainty regarding the choice of treatment, how best to perform it and to consider potential problems and endpoints.

Advance review checklist

Always decide what you are aiming to achieve. Ask yourself the following questions, the answers will be useful when consenting the patient and carrying out the pre-procedure team briefing:

- Is this the correct procedure for this patient at this time? If there is any doubt, it is time to verify the clinical situation with the referring team; if there is still uncertainty, then discuss the case with your boss.
- What are the key steps and sequences in the procedure? Make sure you have a clear plan and know how to use the necessary equipment.
- What is the likelihood of the procedure having the desired technical and clinical outcome? Make sure that the patient and the referring team understand the limitations of the procedure, especially in cases where the clinical benefit is uncertain.
- What are the possible treatment strategies and which is most likely to succeed and least likely to cause harm?
- Does the case require specific equipment? If so, is it in stock or does it need to be ordered?
- What problems are likely to be encountered? Think about what you will do if there is a problem or you are not successful. You should always have a 'Plan B' and, if necessary, little plans C, D and E.
- Might you stop before your objective is reached? It is often better to 'live to fight another day' rather than ploughing on in a spiral of failure, especially if this might have an adverse clinical outcome for the patient – you did remember to warn them about this and document the discussion in the patient record didn't you?

Finally, ask yourself the ME question: would I be happy to have someone with my skill and experience undertake this procedure on me? If the answer is yes, then go ahead but if the answer is no, then either reschedule the patient on a more appropriate list or make sure that you have appropriate assistance from a colleague.

On the day: staff, equipment and room preparation

It is essential to review how the list will run and requirements for individual cases. There is no hard and fast way to do this as long as all of the key aspects are covered.

Daily safety check

Before the list begins Representatives from each of the teams who will be involved (radiologist, nursing, radiography, anaesthesia, surgery, etc.) should review all of the planned cases as a group. Some centres will choose to include a review of individual case management at this time.

It is the responsibility of these staff to disseminate important information to other members of their teams. The meeting should not take place in the absence of essential staff. One individual is responsible for recording the attendance and discussion and ensuring that the daily safety check is recorded in the radiology information system.

The purpose of this check is to:

- Review and agree the order of cases
- Consider complex or high-risk patients – this will include a review of your advance planning
- Consider risks to staff and other patients, such as infection control issues
- Verify that all required equipment is available.

The meeting should not take more than a few minutes assuming everyone has prepared.

Individual patient safety checks

The elements of the safety check are included in Table 2.1 and your institution will have its own version. What follows is intended to explain the ethos that lies behind the checks. If you understand this, you will be able to lead the team effectively through the process.

Table 2.1 Checklist for typical interventional cases

Task	Person responsible	Elements
Pre-procedure case review	Doctor	Review intended procedure: site, side, approach, etc.
	Nurse	Need for sedation, analgesia, anaesthesia
	Radiographer	Monitoring
		Anticipated equipment including patient-specific items, e.g. stent graft, chemoembolization
		Emergency equipment
		Potential difficulties
		Additional equipment, e.g. ultrasound machine
		Important elements of procedure
		Set of room: C-arm position, trolleys, etc.
Pre-procedure checklist	Nurse	Patient ID
		Patient notes
		Allergies/drug reactions
		Pre-procedure test results normal or inform doctor
		Intravenous access
		Hydration
		Premedication
		Antibiotic prophylaxis within previous 60 min
		Analgesia/sedation
		Check correct equipment available
		Bail out kit (covered stents, etc.)
	Doctor	Consent
		Medication required is prescribed
	Radiographer	Request available
		Imaging available
Post-procedure check	Doctor	Operative sheet completed showing procedure, outcomes, complications, aftercare
		Communication with patient, relatives and other carers
		Planned review stated
	Nurse	Sharps disposed safely
		Patient charts completed including prescribed drugs, monitoring
		Specimens labelled and handled correctly
		Handover to ward staff including instructions for aftercare/ analgesia
		Patient given information sheets/instructions for care/contact numbers
	Radiographer	Images reviewed with doctor
		Images archived

Before starting

The team who will perform the case should convene and go through a safety checklist, this should be recorded on the radiology information system and a copy filed in the patient record. How you conduct the safety check is up to your team and it does not really matter so long as everyone takes it seriously and all the bases are covered.

If you use a white board to manage the list you can always call upon your artistic skills and draw a schematic overview of the case and list equipment and drugs. The key elements of the check are as follows.

Introductions Ensure that everyone knows each other. This is particularly important when working with another team from, e.g. intensive care staff coming to the interventional suite, or you are in an unfamiliar environment, e.g. when working in the operating theatre.

Patient identification and consent check Verify that the patient has been identified using appropriate two- or three-step checks (name, date of birth and address) and that there is a valid signed consent form.

Procedure plan Make sure that everyone knows the plan for the procedure, its steps and any anticipated difficult elements. Include patient positioning, the approach, site to be treated and the equipment you intend to use. Confirm that medications and blood products have been prescribed/administered/are available if required.

Equipment check Ensure the team has checked that all the anticipated and 'bale out' kit is available and in the room and that you are informed of anything missing or in short supply (e.g. balloons, stents, embolization coils).

Explanations If the case is complex, who will ensure that everyone knows their roles and responsibilities, e.g. patient monitoring, running nurse, scrub nurse? Pick your strongest team and ensure that the most appropriate individual is in each role.

Final confirmation Ask if anyone has any questions and check that everyone is happy to proceed.

Post-procedure check and aftercare

It is always tempting to think that once you have performed your technical wizardry your work is done. Unfortunately, this is not the case and now is the time for the less glamorous, but still important, aspects of the job.

As soon as the procedure is over, the post-procedure checklist (Table 2.1) should be completed, this can be completed by someone else while you obtain haemostasis, or even better, completed by you while someone you trained pushes on the groin. Following this is the time to sit down (in the UK with a cup of tea) and make an operative record. This should include technical details of the procedure and any implants. It is important to document complications, even if they have been resolved. It is good practice to keep a copy of the operative record on the radiology information system for future reference.

As well as the operative note, it is important to make sure that there is an adequate handover of care to the receiving ward and clinical team. Unlike the safety check, there is no particular ethos required and the individual elements to consider are set out below. It is essential that the person who actually hands over care to ward staff is aware of the key facts and also where you have your notes for handover.

- Will the patient require any special care or analgesia after the procedure?
- Have you handed over care to an appropriate colleague?
- Do the ward nurses require special orders for observations and patient monitoring?
- Do drains or lines need particular care or management?
- If there are potentially predictable problems what precautions are necessary and what actions should be taken if they occur?
- Who should be notified if there is a problem and how are they to be contacted?
- Will you be visiting to review the patient?
- When can the patient be discharged; has a discharge letter been provided and any medications prescribed?
- Is an outpatient appointment necessary, when and with whom?

A particular form of handover is communication with the patient/carer after an outpatient or day-case procedure. It is best to provide written instructions, especially if the patient has received sedation. Make sure that the patient/carer knows who to contact and how to contact them in the event of an emergency.

Table 2.1 indicates the typical elements that should be considered for almost every procedure.

Tip: Fail to plan, plan to fail. Planning helps you and your staff to ensure procedures are performed safely and smoothly, with the minimum of stress for all concerned!

3

Contrast

Most vascular computed tomography (CT) and magnetic imaging resonance (MRI), the vast majority of angiographic procedures, and many nonvascular interventions rely on contrast media to reveal the anatomy. Contrast media can be broadly classified according to their use and also their chemical structure. X-ray contrast affects tissue X-ray attenuation, ultrasound contrast affects tissue and blood reflectivity and MRI contrast affects tissue relaxation times. The Royal College of Radiologists has issued pragmatic guidance on the use of intravascular contrast agents. Discussion in this chapter is confined to contrast media used for angiography and vascular diagnosis.

Intravascular X-ray contrast agents

The two principal categories of X-ray contrast both affect X-ray attenuation. Details of the chemical and physical properties of these agents are extensively discussed in many texts. It helps to be familiar with the different options and their indications, this will be most relevant in cases where there is kidney disease or a history of adverse reaction.

Positive contrast agents These are liquids containing iodine or gadolinium that have greater attenuation than the patient's soft tissues.

Negative contrast This has lower attenuation than the patient's tissues; at present, carbon dioxide gas is the only available option.

Basic principles for using intravascular contrast

Optimal demonstration of anatomy and pathology requires sufficient difference in attenuation between the target tissue and the surroundings, as well as X-ray equipment parameters, e.g. kV and mAs.

The aim is to adequately opacify the vessel but allow a level of grey-scale that allows branches/filling defects to be seen through the contrast. This requires the correct strength contrast in sufficient quantity (volume of contrast) delivered in the right place. If the contrast is too diluted, there will be insufficient change in attenuation, conversely too concentrated contrast can obscure lesions.

As a general principle, the contrast column should opacify the entire vessel segment. To achieve this, the total contrast dose and the duration of the bolus must be correct. Appropriate catheter positions, contrast volumes and flow rates are indicated throughout the diagnostic angiography sections. When the blood flow is slow, it may take several seconds for

the opacified blood to pass through the vessel. Hence, a long contrast bolus is necessary. This is one of the reasons for increasing the volume of contrast to image the more distal vessels. Modern angiography equipment allows integration of multiple images, which has the same effect as increasing the length of the bolus, but it can reduce image quality due to minor degrees of patient movement between frames.

Iodinated contrast media

These are the most frequently used agents. Non-ionic contrast media are recommended in high-risk patients (see below).

Most diagnostic and therapeutic intervention is performed using '300 strength' contrast (300 mg/mL iodine). This density of contrast is fine for pump injections into large vessels where the contrast is diluted by rapid blood flow. For selective hand injections in the vascular system and for non-vascular examinations, 300 strength contrast is diluted with saline to 'two-thirds' or 'half strength'.

Contrast reactions with iodinated contrast media

There are two forms of contrast reaction: direct effects and idiosyncratic responses; these are more common in certain groups of patients and emphasis should be on identifying them, reducing risk and preventing reactions. Up to 2% of patients require treatment for adverse reactions to intravascular iodinated contrast agents. Fortunately, the majority of cases require only observation and minor supportive treatment. Less than 1% are severe but these require prompt recognition and immediate treatment.

Alarm: Contrast reactions should be discussed during the consent procedure.

Direct effects Direct effects are secondary to the osmolality and direct chemotoxicity of the contrast, and they include heat, nausea and pain. More important are the effects on organ systems.

Renal Contrast-induced acute kidney injury (CI-AKI), defined as a rise in creatinine of 0.5–1 mg/dL or 44–88 µmol/L, is common and most likely in patients with chronic kidney disease. Strategies for preventing CI-AKI are discussed in Chapter 1.

Cardiac Cardiac problems are most likely to occur during coronary angiography and are usually manifest as arrhythmias or ischaemia. It is prudent to use non-ionic contrast in patients with ischaemic heart disease or heart failure.

Haematological Significant haematological interactions are uncommon. Non-ionic iodinated contrast can induce clotting if mixed with blood; hence, scrupulous attention to catheter flushing and avoidance of contaminating syringes with blood are essential.

Neurological Most neurological sequelae occur during carotid angiography and are related to angiographic technique. Genuine contrast-related problems are rare and are usually seen in patients with abnormalities in the blood–brain barrier.

Idiosyncratic reactions The mechanism of these reactions is uncertain; vasoactive agents such as histamine, serotonin, bradykinin and complement have been implicated but a causal role has not been established.

Idiosyncratic reactions are classified according to severity.

- **Minor:** Common, ~1 : 30, e.g. metallic taste, sensation of heat, mild nausea, sneezing; these do not require treatment.
- **Intermediate:** Common, ~1 : 100, e.g. urticaria; not life-threatening; these respond quickly to treatment.
- **Severe:** Rare, ~1 : 3000, e.g. circulatory collapse, arrhythmia, bronchospasm, dyspnoea; may be life-threatening; these require prompt therapy. Remember the A, B, C, D approach and do not hesitate to call for help.
- **Death:** Rare, ~1 : 40,000, mostly caused by cardiac arrhythmia, pulmonary oedema, respiratory arrest or convulsions.

Assessing the risk The risk of a contrast reaction varies depending on the circumstances of individual patients; however, the following are associated with an increased risk of a severe idiosyncratic reaction:

- Previous allergic reaction to iodine-containing contrast and shellfish allergy: 10×
- Cardiac disease: 5×
- Asthma: 5×
- General allergic responses: 3×
- Drugs: β-blockers, interleukin-2: 3×
- Age >50 years: 2× risk of death.

Remember that these factors increase the relative risk; the absolute risk remains very low.

Reducing the risk The vast majority of severe and fatal contrast reactions occur within 20 min of administration and therefore it is vital that patients are kept under constant supervision with a cannula in situ during this period. There have been a few isolated reports of delayed hypotensive reactions hours after contrast injection.

The ideal method of reducing risk is to avoid iodine-containing contrast examinations by using other imaging modalities, such as ultrasound or MRI. When this is not possible:

- **Prepare for reaction.** Ensure that resuscitation equipment and drugs are immediately available every time contrast is injected. Make sure that you are familiar with the management of the reaction; most catheter laboratories have charts on the wall to remind you in times of need (note: it is much less stressful to check it out in advance).
- **Use non-ionic contrast agents.** Non-ionic contrast agents certainly reduce the risk of minor reactions and may reduce the risk of more significant reactions.
- **Reassure the patient.** Explain that contrast reactions are unlikely and that the situation is under control. In severe anxiety, short-acting anxiolytic agents may be warranted.
- **Consider steroid pre-medication.** There is no conclusive evidence that oral steroid premedication reduces the risk of moderate–severe reactions but it pays to check whether your department has guidelines on steroid administration.

In the rare patient with a previously documented severe reaction:

1. Try to identify which agent was responsible (and make certain you do not use it again)!
2. Avoid iodinated contrast; use CO_2 or gadolinium or another imaging modality.
3. If this is impossible and the examination is essential:
   - If there is time, seek the opinion of an allergy specialist.
   - Ensure resuscitation personnel, equipment and drugs are immediately available. You may need expert assistance maintaining the airway, so consider enrolling anaesthetic assistance.
   - Monitor the patient carefully.
4. Use non-ionic contrast.

5. Consider steroid premedication in accordance with local guidelines.
6. Reassure the patient.

Treatment of contrast reactions

Warn patients that a sense of warmth, a metallic taste and transient nausea are all common after rapid IV injection of contrast and these effects wear off after a few minutes.

Minor reactions

- **Nausea and vomiting.** Active treatment rarely required. Reassure and monitor patient.
- **Urticaria.** One of the commonest contrast reactions. Localized patches of urticaria do not require treatment. Simply observe and monitor the patient (pulse, BP). Generalized urticaria or localized urticaria in sensitive areas, e.g. periorbital, should be treated by chlorphenamine 20 mg, given slowly by IV injection.
- **Vasovagal/syncope.** Monitor the patient's pulse, BP, oxygen saturation and ECG. Elevate the legs. Establish IV access. Give atropine 0.6–1.2 mg by IV injection for symptomatic bradycardia. Volume expansion with IV fluids for persistent hypotension. If hypotension persists, seek medical support.

Intermediate–severe reactions

Bronchospasm Monitor the patient's pulse, BP, oxygen saturation and ECG.

- Give 100% O_2.
- Treat initially with β-agonist inhaler, e.g. salbutamol.
- Give IV corticosteroids, e.g. 100 mg hydrocortisone. In acute reactions, steroids may work surprisingly quickly, although it can take a few hours for them to achieve full effect.

If there is continuing bronchospasm seek assistance.

- Consider intramuscular epinephrine: 0.3–0.5 mL of 1 : 1000 solution.

Laryngeal oedema/angioneurotic oedema Seek anaesthetic assistance. Monitor the patient's pulse, BP, oxygen saturation and ECG. Give:

- 100% O_2 and watch the oxygen saturation closely.
- Chlorphenamine 20 mg by slow intravenous injection.

Consider:

- Epinephrine intramuscularly (IM) 0.3–0.5 mL of 1 : 1000 solution.
- Get an anaesthetist to assess the airway. Tracheostomy may be required in severe cases.

Severe hypotension Call for support. Hypotension accompanied by tachycardia may indicate vasodilation and increased capillary permeability. Monitor the patient's pulse, BP, oxygen saturation and ECG.

Alarm: Also consider other causes of hypotension related to the patient's underlying diagnosis or procedural complication e.g., bleeding or myocardial infarction.

- Rapid infusion of IV fluids is essential and several litres of fluid replacement may be necessary.
- Epinephrine IM 0.3–0.5 mL of 1 : 1000 solution. In the case of severe circulatory shut down IV epinephrine may be required. This is normally the preserve of expert anaesthetists/physicians but if the patient is severely shocked, consider epinephrine 1 mL (0.1 mg) 1 : 10 000. This should be given with extreme caution by slow IV injection.

Cimetidine, the H_2 receptor antagonist, has been effective in severe reactions resistant to conventional therapy. The drug is given by slow IV infusion (cimetidine 300 mg in 20 mL saline). An H_1 receptor blocker, such as chlorphenamine, should be given first.

MRI contrast agents

Gadolinium

Gadolinium works well as an MRI contrast agent. Its use has been described in X-ray angiography but it is a poor X-ray contrast agent and is often difficult to see on fluoroscopy. Gadolinium is handled in the same way as conventional liquid contrast agents and can be injected by hand or with a dedicated injection pump.

There are many different gadolinium preparations and there is increasing interest in the use of 'blood pool agents' for magnetic resonance angiography (MRA). These have a longer dwell time in the circulation and this improves imaging in the venous phase.

Gadolinium-based agents are much more expensive than iodinated contrast, therefore their use is almost exclusively reserved for MRI and the occasional patient who needs a limited volume of contrast and has a genuine reason to avoid iodinated contrast, e.g. severe contrast reaction.

It is now recognized that gadolinium poses particular risks in patients with renal impairment. Gadolinium-based agents are nephrotoxic in their own right, especially when doses greater than 40 mL are used in MRA.

Nephrogenic systemic fibrosis (NSF)

NSF only occurs in the presence of impaired renal function. The following groups are most vulnerable:

- Patients with acute or chronic kidney disease. NSF has not been described in patients with GFR >60 mL/min per 1.7 m^2. This limits the utility of gadolinium-based agents for MRA and conventional angiography in patients with renal impairment
- Patients in the immediate postoperative period following liver transplant
- Neonates and infants
- Pregnant or breastfeeding women.

When a patient is deemed to be at high risk, there should be careful consideration whether an alternative test would be safer.

Tip: If the patient requires angiography and you have a modern MR scanner, consider performing non-contrast MRA.

Those who require gadolinium contrast should be given the lowest diagnostic dose and a low-risk agent, e.g. a macrocyclic agent, such as gadoterate meglumine (Dotarem) should be used. Ideally, no further study should be performed within 7 days.

Alarm: Informed consent should be obtained from high-risk patients requiring gadolinium-based contrast.

Negative contrast agents – carbon dioxide (CO_2)

Carbon dioxide angiography is exclusively performed as subtraction angiography (DSA) and additional software may be necessary to optimize the image. CO_2 dissolves rapidly in blood

and is excreted through the lungs. Consider using CO_2 when there is a contraindication to conventional iodinated contrast and in a few circumstances where CO_2 is a superior contrast agent.

Carbon dioxide is most commonly used for the following reasons:

- History of severe reaction to iodinated contrast
- Renoprotection
- Where there is another advantage, such as the use of CO_2 for wedged hepatic venography.

Alarm: There is a risk of cerebral toxicity with CO_2 and for this reason it should never be used intra-arterially above the diaphragm or intravenously in patients with right-to-left shunts.

Equipment

- Basic angiography set
- Medical-grade CO_2 from a disposable cylinder:
  - Reusable cylinders may be contaminated with water or rust particles; hence the need for a disposable system. The bacterial filter is a further safeguard. In an ideal world, one would use disposable stainless steel cylinders.
- Standard bacterial filter (from a blood-giving set)
- High-pressure connector
- Three-way tap
- Lockable stopcock for each syringe
- Sixty-mL Luer lock syringes.

The circuit is set up as shown in Figure 3.1.

Alarm: The pressurized CO_2 must never be connected directly to the patient, as this risks inadvertent injection of a large volume of gas that may cause a 'vapour lock'.

Injecting CO_2

You can inject by hand or via a dedicated pump. CO_2 gas has very low viscosity and so is very readily injected even through small catheters. Injecting a colourless, odourless and invisible

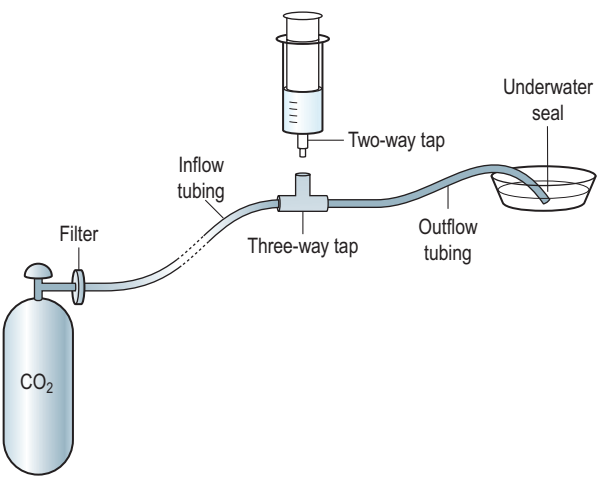


Fig. 3.1 Preparation of CO_2 for hand injection.