Applied Anatomy for Anaesthesia and Intensive Care

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Preface

Anatomical examination of the human body is a science which has been studied for over 3500 years. Anaesthesia and intensive care medicine are comparatively new specialties, evolving mostly in the twentieth century. However, it is only with the ready availability of high-quality portable ultrasound machines that the relevance and applicability of anatomy to these specialties has been brought so clearly into the working environments of the operating room and intensive care unit. The anatomical science once studied as an undergraduate now seems fundamental to our core knowledge and essential to improve the safety and quality of care delivered in both perioperative and critical care settings.

This book aims to distil years of anatomical study into a useful resource for the practising anaesthetist or intensive care specialist. By presenting only the most relevant anatomy in a concise and easy-to-read format, and by correlating it to the images gleaned from ultrasound, radiographic and fibreoptic technologies, we have produced an essential text for reference at the bedside, in the office and at home. However, in acknowledgement of the fact that not all readers will have access to, or be familiar with, such equipment, traditional procedural techniques such as those involving landmarks or nerve stimulator approaches are also described in full. Useful mnemonics and easily reproducible sketches of important anatomical areas are also provided for those studying towards postgraduate examinations in anaesthesia or intensive care medicine.

In summary, this text is an invaluable reference and study guide for practising anaesthetists and critical care physicians who wish to revise, develop or advance their anatomical knowledge and procedural skills, thereby increasing the scope, quality and safety of their practice.
Acknowledgements

*From Andy:*
To my wonderful family. To Lindsay for being so hugely patient and tolerant, and to Emily and Alex for bringing us so much joy.

*From Chris:*
To my wonderful family Hannah, Liberty and Charlie. For your patience and all the late nights.

*From James:*
To Theresa, Jasna, Kasia and Roxy. Thank you for your patience and understanding. To my mother. Thank you for inspiring creativity. To the memory of my dear father. Thank you for the work ethic.

Also to our friend and colleague Guy Matthew Jordan, 1972–2013.
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Disclaimer

Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required. The authors and the publisher of this work have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication. However, in view of the possibility of human error or changes in medical sciences, neither the authors nor the publisher, nor any other party who has been involved in the preparation or publication of this work, warrant all the information contained herein is in every respect accurate or complete, and they disclaim all responsibility for any errors or omissions or for the results obtained from use of the information contained in this work. Readers are encouraged to confirm the information contained herein with other sources. For example and in particular, readers are advised to check the product information sheet included in the package of each drug they plan to administer, to be certain that the information contained in this work is accurate and that changes have not been made in the recommended dose or in the contraindications for administration. This recommendation is of particular importance in connection with new or infrequently used drugs. Natural anatomical variation exists between individuals, and the authors cannot be accountable for the implication that this brings to clinical practice when using this text. The authors are not accountable for the actions of any person following the procedural guidance contained within this text. All persons must be appropriately trained by conventional means and be completely familiar with the procedures and equipment employed before performing any procedure or using any piece of equipment on patients, particularly when doing so in an unsupervised capacity. The risks and complications listed cannot be fully comprehensive, and the authors are not accountable for any untoward event that may arise and that is or is not listed in the text.
How to use this book

This book is designed to be used in two ways. It is designed as a reference and core knowledge text for those working towards postgraduate examinations in anaesthesia and intensive care medicine. The book is organised by body region and contains useful mnemonics and easily reproducible sketch diagrams for key areas of the body. We hope it will also be a useful reference aid for those wishing to refresh this knowledge in the years after examinations. It is also designed for those wishing to learn, revise and develop their procedural skills. All of the procedures are described in text boxes, which are located close to the anatomy relevant to that procedure. Anatomical illustrations are correlated with ultrasound images where possible. The plane of the ultrasound beam is shown on the anatomical illustration by a grey ‘pane’ (akin to a pane of glass), showing how the structures are bisected by the ultrasound beam. Please note, nerve blocks of the brachial plexus which are placed around or proximal to the clavicle are described in the neck chapter. Blocks placed distal to the clavicle are described in the upper limb chapter. We hope you find the text useful and informative.

Universal procedural advice for peripheral nerve blockade

Multiple peripheral nerve block techniques are described in this book. Each technique contains some steps unique to that block and some which are universal. For brevity, and so that the reader can more rapidly identify the salient features of the specific block, universal pre- and post-procedure steps are listed here.

- Consent is required for all procedures.
- Procedures should be performed in a well-lit, clean environment.

Indications

Perioperative anaesthesia, postoperative analgesia and treatment of acute or chronic pain.

Absolute contraindications

- Patient refusal.
- Cutaneous infection at block insertion site.
- Allergy to local anaesthetic agent.

Relative contraindications

- Coagulopathy – see Table 1.
- Uncooperative patient.
- Patients with long-standing diabetes, peripheral neuropathy, sepsis or severe peripheral vascular disease may not experience nerve stimulation with a current intensity of < 0.5 mA, increasing the difficulty of locating the end point for injection.
### Pre-procedure checks

- Airway and ventilation equipment.
- IV access.
- Resuscitation drugs and equipment.
- Trained assistant.
- Conscious sedation and analgesia may be required to improve patient experience. Small titrated doses of fentanyl (up to 50 mcg) and propofol (target-controlled infusion or small boluses up to 50 mg) are effective.
- Supplementary oxygen.
- Aseptic technique. Meticulous skin preparation with 2% chlorhexidine gluconate in 70% isopropyl alcohol, allowed to dry fully. Sterile gloves and drapes.
- The ultrasound probe should be covered with a sterile probe cover.
- Nerve stimulator function should be checked prior to use – sufficient battery power, visual inspection of cables for damage and positive lead attached to the patient with an ECG gel sticker.
- 1–3 ml of local anaesthetic is infiltrated subcutaneously at the site of block needle insertion.

### Complications

- Failure.
- Local anaesthetic toxicity.

### Post-procedure checks

- Follow-up is required to establish block success and recovery.
- Care of the anaesthetised area/limb – protection from excessive heat, cold or trauma.

### Anticoagulants and peripheral/central neuraxial blocks

The variety of anticoagulants being taken by patients is increasing. Judgement must always be exercised on the merits and risks of performing blocks in patients on anticoagulants (and if so when) or whether the drugs should be stopped prior to performing the block. Clearly stopping the drug requires an assessment of the underlying condition of the patient and an appreciation of the anaesthetic and surgical risks and benefits.

At time of writing, the following tables represent the most up-to-date information and advice on anticoagulants commonly in use, and they should help inform the reader on the benefits and risks of block performance in the anticoagulated patient.
Table 1 Recommendations related to drugs used to modify coagulation. Recommended minimum times are based in most circumstances on time to peak drug effect + (elimination half-life × 2), after which time < ¼ of the peak drug level will be present. For those drugs whose actions are unrelated to plasma levels, this calculation is not relevant. Data used to populate this table are derived from ASRA and ESRA guidelines [1,2] and information provided by drug manufacturers. These recommendations relate primarily to neuraxial blocks and to patients with normal renal function except where indicated.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Time to peak effect</th>
<th>Elimination half-life</th>
<th>Acceptable time after drug for block performance</th>
<th>Administration of drug while spinal or epidural catheter in place</th>
<th>Acceptable time after block performance or catheter removal for next drug dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heparins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFH sc prophylaxis</td>
<td>&lt; 30 min</td>
<td>1–2 h</td>
<td>4 h or normal APTT</td>
<td>Caution</td>
<td>1 h</td>
</tr>
<tr>
<td>UFH iv treatment</td>
<td>&lt; 5 min</td>
<td>1–2 h</td>
<td>4 h or normal APTT</td>
<td>Caution²</td>
<td>4 h</td>
</tr>
<tr>
<td>LMWH sc prophylaxis</td>
<td>3–4 h</td>
<td>3–7 h</td>
<td>12 h</td>
<td>Caution</td>
<td>4 h</td>
</tr>
<tr>
<td>LMWH sc treatment</td>
<td>3–1 h</td>
<td>3–7 h</td>
<td>24 h</td>
<td>Not recommended</td>
<td>4 h</td>
</tr>
<tr>
<td><strong>Heparin alternatives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danaparoid prophylaxis</td>
<td>4–5 h</td>
<td>24 h</td>
<td>Avoid (consider anti-Xa levels)</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Danaparoid treatment</td>
<td>4–5 h</td>
<td>24 h</td>
<td>Avoid (consider anti-Xa levels)</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Bivalirudin</td>
<td>5 min</td>
<td>25 min</td>
<td>10 h or normal APTT</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Argatroban</td>
<td>30–3 min</td>
<td>30–35 min</td>
<td>4 h or normal APTT</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Fondaparinux prophylaxis</td>
<td>1–2 h</td>
<td>17–20 h</td>
<td>36–42 h (consider anti-Xa levels)</td>
<td>Not recommended</td>
<td>6–12 h</td>
</tr>
<tr>
<td>Fondaparinux treatment</td>
<td>1–2 h</td>
<td>17–20 h</td>
<td>Avoid (consider anti-Xa levels)</td>
<td>Not recommended</td>
<td>12 h</td>
</tr>
<tr>
<td><strong>Antiplatelet drugs NSAIDs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin</td>
<td>1–12 h</td>
<td>1–12 h</td>
<td>No additional precautions</td>
<td>No additional precautions</td>
<td>No additional precautions</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>12–24 h</td>
<td>Not relevant; irreversible effect</td>
<td>No additional precautions</td>
<td>No additional precautions</td>
<td>No additional precautions</td>
</tr>
<tr>
<td>Prasugrel</td>
<td>12–24 h</td>
<td>7 days</td>
<td>Not relevant; irreversible effect</td>
<td>7 days</td>
<td>No additional precautions</td>
</tr>
<tr>
<td>Ticagrelor</td>
<td>15–30 min</td>
<td>7 days</td>
<td>Not relevant; irreversible effect</td>
<td>7 days</td>
<td>No additional precautions</td>
</tr>
<tr>
<td>Tirosiban</td>
<td>&lt; 5 min</td>
<td>4–8 h</td>
<td>8 h</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Epifloxacide</td>
<td>4–8 h</td>
<td>4–8 h</td>
<td>8 h</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Aboximel</td>
<td>&lt; 5 min</td>
<td>24–18 h</td>
<td>48 h</td>
<td>Not recommended</td>
<td>6 h</td>
</tr>
<tr>
<td>Dipiridamole</td>
<td>75 min</td>
<td>10 h</td>
<td>No additional precautions</td>
<td>No additional precautions</td>
<td>6 h</td>
</tr>
</tbody>
</table>
Oral anticoagulants: Warfarin
- 3–5 days 4–5 days INR ? 1.4
- Not recommended After catheter removal

Rivaroxaban prophylaxis\(^2\) (CrCl > 30 ml min\(^{-1}\))
- 3 h 7–11 h 18 h
- Not recommended 6 h

Rivaroxaban treatment\(^2\) (CrCl > 30 ml min\(^{-1}\))
- 3 h 7–11 h 48 h
- Not recommended 6 h

Dabigatran prophylaxis or treatment\(^2\)
- (CrCl > 30 ml min\(^{-1}\)) 0.5–2.0 h 12–17 h 48 h
- Not recommended 6 h

- (CrCl 30–50 ml min\(^{-1}\)) 0.5–2.0 h 15 h 72 h
- Not recommended 6 h

- (CrCl 50–80 ml min\(^{-1}\)) 0.5–2.0 h 18 h 96 h
- Not recommended 6 h

Apixaban prophylaxis
- 2–4 h 12 h 24–18 h
- Not recommended 6 h

Thrombolytic drugs
- Alteplase, anistreplase, reteplase, streptokinase
- < 5 min 4–24 min 10 days
- Not recommended 10 days

UFH, unfractionated heparin; sc, subcutaneous; APTT, activated partial thromboplastin time ratio; iv, intravenous; LMWH, low molecular weight heparin; NSAIDs, non-steroidal anti-inflammatory drugs; INR, international normalised ratio; CrCl, creatinine clearance.

Notes to accompany Table 1
1. The dangers associated with the administration of any drug that affects coagulation while a spinal or epidural catheter is in place should be considered carefully. There are limited data on the safety of the use of the newer drugs in this Table, and they are therefore not recommended until further data become available. The administration of those drugs whose entry in this column is marked as ‘caution’ may be acceptable, but the decision must be based on an evaluation of the risks and benefits of administration. If these drugs are given, the times identified in the column to the left (‘Acceptable time after drug for block performance’) should be used as a guide to the minimum time that should be allowed between drug administration and catheter removal.

2. It is common for intravenous unfractionated heparin to be given a short time after spinal blockade or insertion of an epidural catheter during vascular and cardiac surgery. Local clinical governance guidelines should be followed and a high index of suspicion should be maintained if any signs attributable to vertebral canal haematoma develop. Consider increasing to 24 h if block performance is traumatic.

3. Low molecular weight heparins are commonly given in prophylactic doses twice daily after surgery, but many clinicians recommend that only one dose be given in the first 24 h after neuraxial blockade has been performed.

4. Time to normal platelet function rather than elimination half-life.

5. Manufacturer recommends caution with use of neuraxial catheters.

References

Table 2 Relative risk related to neuraxial and peripheral nerve blocks in patients with abnormalities of coagulation.

<table>
<thead>
<tr>
<th>Block category</th>
<th>Examples of blocks in category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher risk</td>
<td>Epidural with catheter</td>
</tr>
<tr>
<td></td>
<td>Single-shot epidural</td>
</tr>
<tr>
<td></td>
<td>Spinal</td>
</tr>
<tr>
<td></td>
<td>Paravertebral blocks</td>
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<tr>
<td></td>
<td>Paravertebral block</td>
</tr>
<tr>
<td></td>
<td>Lumbar plexus block</td>
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<tr>
<td></td>
<td>Lumbar sympathectomy</td>
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<tr>
<td></td>
<td>Deep cervical plexus block</td>
</tr>
<tr>
<td>Deep blocks</td>
<td>Coeliac plexus block</td>
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<tr>
<td></td>
<td>Stellate ganglion block</td>
</tr>
<tr>
<td></td>
<td>Proximal sciatic block (Labat, Raj, sub-gluteal)</td>
</tr>
<tr>
<td></td>
<td>Obturator block</td>
</tr>
<tr>
<td></td>
<td>Infracavicular brachial plexus block</td>
</tr>
<tr>
<td></td>
<td>Vertical infracavicular block</td>
</tr>
<tr>
<td></td>
<td>Supraclavicular brachial plexus block</td>
</tr>
<tr>
<td>Superficial perivascular blocks</td>
<td>Popliteal sciatic block</td>
</tr>
<tr>
<td></td>
<td>Femoral nerve block</td>
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<tr>
<td></td>
<td>Intercostal nerve block</td>
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<tr>
<td></td>
<td>Interscalene brachial plexus block</td>
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<tr>
<td>Fascial blocks</td>
<td>Axillary brachial plexus block</td>
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<tr>
<td></td>
<td>Ilio-inquinal block</td>
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<tr>
<td></td>
<td>Ilio-hypogastric block</td>
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<tr>
<td></td>
<td>Transversus abdominis plane block</td>
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<tr>
<td></td>
<td>Fascia lata block</td>
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<tr>
<td>Superficial blocks</td>
<td>Forearm nerve blocks</td>
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<tr>
<td></td>
<td>Saphenous nerve block at the knee</td>
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<tr>
<td></td>
<td>Nerve blocks at the ankle</td>
</tr>
<tr>
<td></td>
<td>Superficial cervical plexus block</td>
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<tr>
<td></td>
<td>Wrist block</td>
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<tr>
<td></td>
<td>Digital nerve block</td>
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<tr>
<td>Normal risk</td>
<td>Local infiltration</td>
</tr>
</tbody>
</table>

Notes to accompany Table 2

There have only been 26 published reports of significant haemorrhagic complications of peripheral nerve and plexus blocks. 1. Half of these occurred in patients being given anticoagulant drugs and half in patients with normal coagulation. Patient harm has derived from:

- Spinal haematoma after accidental entry into the spinal canal during attempted paravertebral blocks as defined in the Table.
- Exsanguination.
- Compression of other structures, e.g. airway obstruction, occlusion of major blood vessels or tissue ischaemia.

The one death in this series was that of a patient on clopidogrel who underwent a lumbar plexus block and subsequently exsanguinated. The majority of the 26 cases underwent deep blocks or superficial perivascular blocks. From these data, and from other data relating to neuraxial blocks, we have placed blocks in the order of relative risk shown in the Table. Catheter techniques may carry a higher risk than single-shot blocks. The risk at the time of catheter removal is unlikely to be negligible. Ultrasound-guided regional anaesthesia, when employed by clinicians experienced in its use, may decrease the incidence of vascular puncture, and may therefore make procedures such as supravacularis blocks safer in the presence of altered coagulation.