The feline humerus

An anatomical study with relevance to external skeletal fixator and intramedullary pin placement

S. J. Langley-Hobbs[1], M. Straw[2]
[1]The Queens Veterinary School Hospital, The Department of Veterinary Medicine, University of Cambridge, Cambridge, U.K.
[2]Beechwood Veterinary Hospital, Bessacarr, Doncaster, South Yorkshire, U.K.

Summary
The humeri of eleven feline cadavers were dissected and safe anatomical areas for placing external skeletal fixator pins were determined. Relevant measurements taken of the humeral condyle enabled a determination of a safe pin diameter range of 1.5 to 2.2 mm for transcondylar pins. Further anatomical measurements allowed recommendations to be made to angle pins in the distal humerus in a distolateral proximomedial direction so that the ESF pin penetrates the far cortex at least 20 mm proximal to the medial epicondyle in order to avoid pin penetration of the supracondylar foramen. Cross sections taken of the distal humerus revealed that passage of an IM pin into the medial aspect of the humeral condyle was possible in less than half the cases.

Keywords
Feline, humerus, external skeletal fixator, intramedullary pin

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Introduction

The aim of the study was to determine safe corridors or areas for external skeletal fixator pin insertion in the feline humerus and whether it was feasible to pass humeral intramedullary pins into the medial condyle, as recommended in the dog (1). The humeri of eleven feline cadavers were dissected. No safe corridors for pin insertion could be identified in the feline humerus but safe areas were present in the craniolateral proximal humerus and in the region of the lateral epicondyle (11). Relevant measurements taken of the distal humerus determined that, in order to avoid placing an external skeletal fixator pin into the supracondylar foramen, the pin should be placed so that it merges through the medial cortex at least 20 mm proximal to the medial epicondyle. Measurements of the minimum humeral condylar diameter enabled a safe diameter of between 1.5 mm and 2.2 mm for a transcondylar external fixator pin to be determined. Cross sections of the distal humerus revealed that passage of an IM pin into the medial condyle was possible in only seven of 17 humeri, and in these, a safe maximum pin diameter of only 1.6 mm was determined.

To a large extent, success of a fracture fixation method depends on correct implant application and a sound knowledge of both skeletal and soft tissue anatomy. It is important that the differences in anatomy between the canine and feline distal humerus are understood as they dictate position, method of application and size of implants used. The feline humerus is generally straighter and smaller than the canine. There is a supracondylar foramen located proximal to the medial epicondyle in the cat and a true supratrochlear foramen is absent. The median nerve and brachial artery pass through the supracondylar foramen before continuing into the antebrachium and distal limb.

The purpose of this study was to highlight the salient anatomical features, particularly in the distal humerus and determine the pertinent dimensions and locations in this area which must be considered when using either an intramedullary pin (IM) and/or an external skeletal fixator (ESF) in the feline humerus. Safe corridors and areas for insertion of ESF pins in the feline humerus were also determined. A safe corridor is a longitudinal region through which pins can safely be inserted as they do not contain important neurovascular or musculotendinous units; hazardous corridors contain musculotendinous units but without important neurovascular structures, and finally, unsafe corridors contain both musculocutaneous units and neurovascular structures (11). Proximal limb bones, such as the femur and humerus, do not have safe corridors for pin insertion; therefore hazardous corridors are identified as the safest areas (11).

Materials and methods

Eleven feline cadavers were weighed and sexed. The forelimbs of two of the feline cadavers were skinned and carefully dissected in order to study the muscular, vascular and neural tissue surrounding the humerus. Reference to anatomical texts (2, 3, 4, 6, 9) was made to compare the anatomy between the dog and cat. The information obtained enabled the determination of corridors for pin insertion within the feline humerus (Fig. 1).

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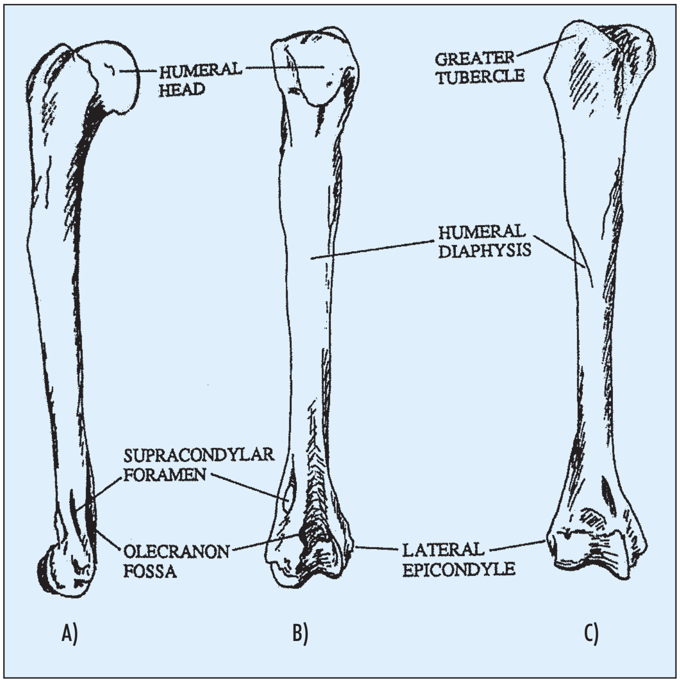

Fig. 1 Annotated diagrams of the A) medial, B) caudomedial and C) cranial views of the feline humerus.

The remaining humerii were used for studying bony dimensions. All of the measurements were made using callipers to an accuracy of 0.5 mm (millimetres). Radiographs of the humeri were taken to assess the skeletal maturity of each cat. From the results of a study by Smith (14) the approximate age was estimated from the radiographic appearance of the growth plates. If any of the humeri were short and the cats were not skeletally mature they were to be excluded from the study.

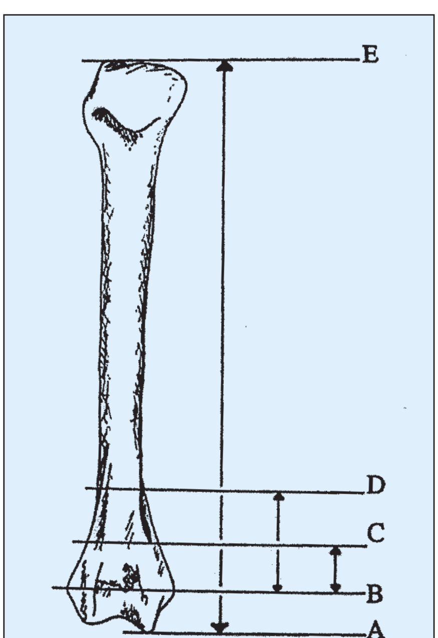

Fig. 2 Diagram of the caudocranial view of the feline humerus showing the relevant anatomical landmarks used to take measurements.

External skeletal fixation

In order to give advice regarding pin placement for external skeletal fixation pins, measurements were taken to determine both the mean sizes of cat humerii and the position of anatomical structures. The measurements were taken from the macerated humeri between the anatomical landmarks listed below (Fig. 2).

- A – the most distal aspect of the medial condyle.
- B – a line between the medial and lateral epicondyles perpendicular to the axis of the bone.
- C – the most distal aspect of the supracondylar foramen on the cranial surface of the bone.
- D – the most proximal aspect of the supracondylar foramen on the caudal surface of the bone.
- E – the most proximal aspect of the greater tubercle.

The supracondylar foramen runs in a caudoproximal to craniodistal direction. In order to determine its maximum dimensions, measurements were taken from the caudal aspect proximally and the cranial aspect distally.

Measurements were made between the points as listed below:

The distance between lines B and D
The distance between lines B and C
The distance between lines A and E (the length of the humerus).
The minimum diameter of the condyle taken in a cranio-caudal direction (F) (Fig. 3).

Statistical analysis

The mean values were calculated along with standard deviation (S.D) and standard error of the mean (S.E.M). A 95% confidence limit was calculated on the basis of a Student's t distribution according to the equation Population mean = sample mean +/- 2.306S.E.M. The mode was also calculated.

Transcondylar pins

In order to determine the maximum pin size to place in a transcondylar fashion, 20%-33% of the mean dimension (F) was calculated (5, 7). Visual assessment was made of the feline humeral condyle with regard to its three dimensional shape in order to make recommendations concerning landmarks for transcondylar pin placement.

Intramedullary pins

In order to determine appropriate IM pin dimensions that can be accommodated by the distal humerus, the bone was osteotomised at the most proximal part of the trochlea, perpendicular to the axis of the bone, and a second parallel osteotomy was made 5 mm proximal to this. IM pins of varying sizes (1.1 mm, 1.6 mm, 2.0 mm and 2.4 mm) were inserted into the humerus from the lateral aspect of the greater tubercle through the osteotomised segment and into the medial condyle. It was also determined whether the pin could safely be passed whilst maintaining normal anatomical alignment and without fracturing the bone or penetrating the olecranon fossa. If safe passage could be achieved into the medial aspect of the humeral condyle, the maximum size of the medullary canal was recorded (H). If passage was not possible into the medial condyle the maximum size of the IM canal in the supracondylar area was determined (G).

Results

Nine of the cats were male and two were female: their average weight was 3.74 kg (Table 1). In all of the cases the cause of death was unknown. Nine of the eleven cats were skeletally mature. In two cats (4 and 9) some ossification centres were unfused, however, the lengths of the humeri of these two cats were not shorter than the other nine, hence they were included in the study.

Safe areas for external skeletal fixator pin placement

Safe corridors for ESF pin placement were not identified, but two safe areas were present. The first was on the craniolateral aspect of the proximal humerus, bordered by the insertion of the supraspinatus muscle dorsally, the deltoideus muscle caudolaterally and the cleidobrachialis muscle craniolaterally. The cephalic vein runs cranially across the insertion of the supraspinatus on the greater tubercle of the humerus before joining the external jugular vein in the neck. The clavicle, joining the brachiocephalicus and cleidobrachialis muscles in the cat, can be palpated and this lies craniolateral to the insertion of the supraspinatus. The safe area ends in a 'V' approximately a third of the way down the humerus where the acromial head of the deltoideus meets the cleidobrachialis at the most distal aspect of the deltoid tuberosity. There was also a second safe area in the region of the lateral epicondyle.

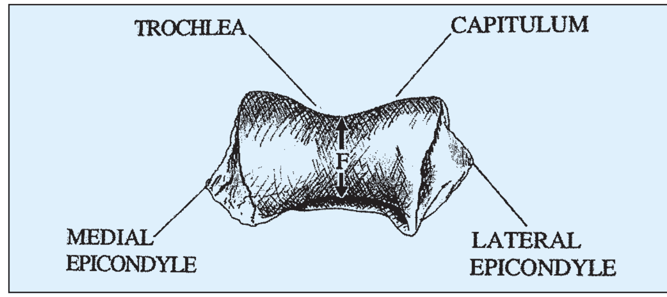

Fig. 3
Diagram of the distal aspect of the feline humeral condyle showing where the measurement (F) was made at the narrowest part of the condyle.

Dimensions

The measurements of the distance between the medial epicondyle and the most proximal aspect of the supracondylar foramen (BD) are shown in Table 1. The mean distance is calculated as 18.4 mm (S.D. 1.60, S.E.M 0.34). Using the Student's t distribu-

Table 1 Details and measurements of the feline cadaveric humeri.

Cat Number	Sex	Weight (kg)	Leg Number	Length (mm)	BD (mm)	BC (mm)	F (mm)	H (mm)	G (mm)
1	M	2.72	R1	112.5	17.5	6.0	7.5	1.5	
			L1	113.0	19.5	5.0	8.0	1.5	
2	F	2.07	R2	95.5	16.5	4.0	7.0		
			L2	96.0	17.5	5.0	7.0		1.5
3	M	5.24	R3	111.0	21.0	7.0	7.0	2	
			L3	111.5	21.5	7.0	7.0	2.5	
4	M	3.63	R4	96.0	16.5	5.5	7.0		
			L4	97.0	16.5	5.0	7.5		2.5
5	M	4.54	R5	104.5	19.5	5.0	7.5		2.5
			L5	104.0	20.0	4.5	7.5		2.5
6	M	4.34	R6	99.0	17.5	7.0	7.0		2.5
			L6	99.0	18.0	6.5	7.5		2
7	M	3.43	R7	105.5	20.0	4.5	7.5	1	
			L7	105.5	20.5	5.5	7.5	1.5	
8	M	3.43	R8	96.0	18.0	7.5	7.0		
			L8	96.0	17.5	8.0	7.5	1.5	
9	F	3.54	R9	102.0	19.0	7.5	7.5		2.5
			L9	101.5	19.5	8.0	7.5		2.5
10	M	4	R10	104.5	16.0	6.0	8.0		2.5
			L10	104.5	16.5	7.5	8.0		2.5
11	M	4.22	R11	90.0	18.5	6.5	7.0		
			L11	90.0	18.5	7.0	7.0		
MEAN		3.74		93.4	18.4	6.2	7.4	1.6	2.4
S.D.		_		_	+/-1.60	+/-1.23	+/- 0.35	_	_
S.E.M.		_		_	0.34	0.26	0.08	_	_

kg = kilogram, R=Right, L = Left, S.D. = Standard deviation, S.E.M. = Standard error of the mean, mm = millimeter, Max.=maximum, diam. = diameter, med = medial, cond = condyle, IM=intramedullary, F = diameter of condyle at narrowest aspect, H = maximum size of intramedullary canal in medial aspect of humeral condyle (when present). G = maximum intramedullary canal diameter in supratrochlear area of bone (when pin passage not possible into medial aspect of humeral condyle) tion, it can be said with 95% confidence that the population mean lies between the values 17.61 mm and 19.19 mm.

The mean distance between points B and C, which represent the distance between the most distal part of the foramen and the medial epicondyle, is calculated as 6.2 mm (S.D. 1.23). Using the t distribution it can be said with 95% confidence that the population mean lies between the 5.56 mm and 6.76 mm.

The mean minimal condyle diameter (F) (Table 1) is 7.4 mm (S.D. 0.35); therefore the population mean lies between 7.19 mm and 7.54 mm. 20% to 33% of this mean minimum condylar diameter was calculated as1.5 to 2.2 mm.

From visual assessment of the feline humeral condyle, the landmarks for transcondylar pin placement are from just cranial to the lateral epicondyle, to craniodistal to the medial epicondyle.

Intramedullary pin placement

Ten of the left forelimbs and seven of the right forelimbs were used for this part of the study. It was only possible in seven of the seventeen humeri to pass an IM pin safely into the medial aspect of the humeral condyle (Table 1). From the maximum intramedullary canal dimensions the mean maximum safe pin diameter (H) was calculated as less than or equal to 1.6 mm. In the remaining ten humeri the median maximum intramedullary canal dimension was 2.4 mm so the maximum safe IM pin diameter (G) was calculated as less than or equal to 2.4 mm. In all of the latter cases, the medullary canal was absent by the level of the distal aspect of the supracondylar foramen.

Discussion

Safe corridors and ESF pin placement

The use of ESF in the humerus, in both the cat and dog, is restricted to unilateral frames or a modified unilateral configuration (10). Due to the anatomy of the limb, particularly in the cat, safe pin placement is limited. In both dogs (12) and cats there are no safe corridors for ESF pin insertion in the humerus, only hazardous corridors which are considered the safest areas (11).

The concept of safe, hazardous and unsafe corridors is accepted terminology when considering insertion points for external fixator pins (11, 12). A hazardous corridor contains musculotendinous units (11). The term ‘hazardous’ is synonymous with risky or perilous, which is perhaps too extreme a term to use in all circumstances. It may be more suitable to use ‘safe’ as opposed to “hazardous” when describing musculotendinous penetration in association with low morbidity.

In dogs, there is a safe area in the region of the lateral epicondyle in which a fixator pin can be placed so that it is angled proximal to the supratrochlear foramen. Placement of a pin in a similar manner in the cat would result in it being sited through, or very close to, the supracondylar foramen and the structures that run through it. The results of this study suggest that pins should be placed at least 20 mm proximal to the medial epicondyle to avoid penetration of the foramen. However, the unsafe area for pin insertion described in the canine humerus, where the radial nerve runs over the brachialis muscle in the middle third of the humerus (12), also applies in the feline humerus. Therefore it is important that a pin placed in this region is angled in a distolateral to proximomedial direction in order to avoid penetration or damage of the nerve on the lateral aspect of the bone. If in doubt, a limited open surgical approach should be used so that the radial nerve can be identified and avoided.

Transcondylar ESF pin placement

Many humeral fractures in both cats and dogs affect the distal bone. To optimize ESF stiffness, it is preferable to spread pins out across the whole bone, hence it is often necessary and optimal to place the most distal pin across the humeral condyle. The humeral condyle in both dogs and cats is hour-glass in shape (Fig. 3) and if pin placement is inaccurate there is a risk of joint penetration. Knowing the minimum dimension of the condyle can aid in selecting an appropriate size of pin, which should help avoid both the occurrence of iatrogenic fractures and impairment of motion in the elbow joint subsequent to inadvertent joint penetration. In the dog it is advised that the pin or screw is started just cranial and distal to the lateral epicondyle (15) and that it then penetrates the medial bone in the region of the medial epicondyle. Our study results indicate that in the cat, the pin should be angled from just cranial to the lateral epicondyle and exit the bone craniodistal to the medial epicondyle, in order to avoid joint penetration.

Recommendations of a maximum ESF pin diameter of 20% – 33% of the diameter of diaphyseal bone have been made to minimize iatrogenic fracture or the stress riser effect (5, 7). The results of this study show the mean minimum condylar diameter to be 7.4 mm. Similar recommendations are not available for maximum pin size placement in cancellous bone so, following the previous guidelines for cortical bone, for a mean condylar diameter of 7.4 mm, it was calculated that a pin of between 1.5 mm and 2.2 mm diameter could be used when placed in a transcondylar position. The dimension guide is particularly relevant if using a positive profile threaded pin as the smallest pins routinely available may approach or exceed these size guidelines.

For humeral fractures affecting the supracondylar area in dogs, it may be useful to place two ESF pins in the condyle. The first pin is placed routinely in a transcondylar fashion, and the second pin is angled just proximal to the lateral epicondyle and directed to just distal to the medial epicondyle (13). The placement of two pins in this way in the feline humerus will prove difficult, if not impossible, due to the shape and small diameter of the condyle and the presence of the supracondylar foramen. An alternative method for stabilizing these distal humeral fractures would be to use one full pin in the condyle and attach it to the lateral side of the fixator via a curved acrylic or stainless steel bar (16, 8).

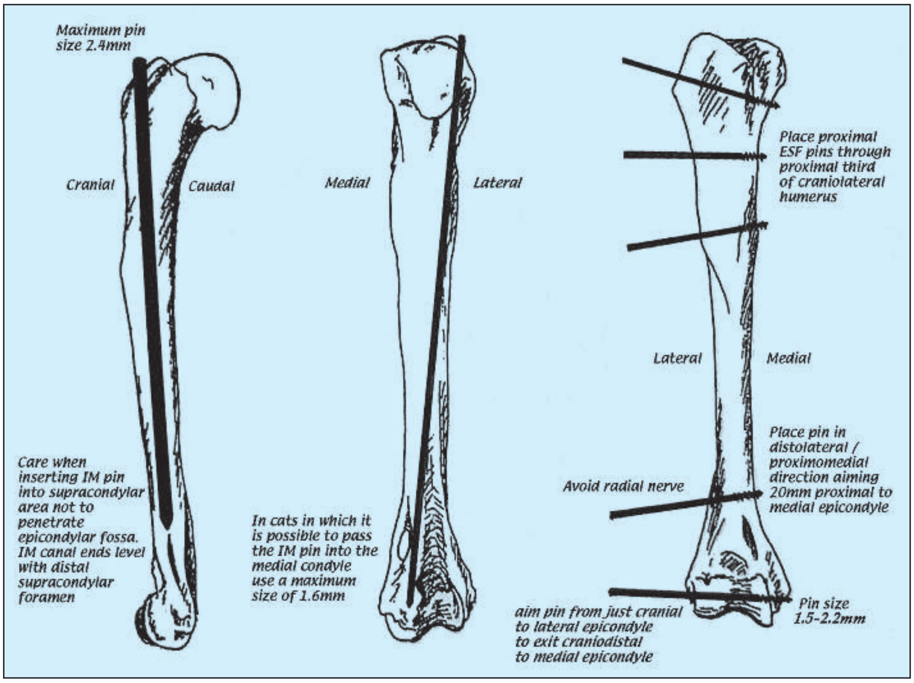

Fig. 4 Diagram summarizing placement and dimension of IM and ESF pins in the feline humerus.

Intramedullary pin placement

When placing a normograde IM pin in a humerus, the point of insertion on the craniolateral greater tubercle (16) should be used in both the cat and the dog, and the pin directed in a medial direction down the medullary canal. In dogs, it is recommended that the pin be passed right into the medial epicondyle. In the majority of cats it was not possible to pass an IM pin through the medial epicondylar ridge into the medial aspect of the condyle because of the absence of an IM canal. Forcible attempts at passing a pin in these cases will therefore result in either fracture of the bone or penetration of the olecranon fossa. When using an IM pin in a cat, the fracture should be assessed carefully as to whether it is necessary for adequate stability to pass the IM pin right into the humeral condyle. If this is desirable, then it may be possible to determine from orthogonal preoperative radiographs (and craniolateral/caudomedial oblique views) of the unaffected humerus whether passage into the medial aspect of the humeral condyle can be achieved. Alternatively, the assessment can be made intraoperatively.

In the majority of cat humerii it was not possible to pass the IM pin through the epicondylar crest into the medial humeral condyle without creating iatrogenic fractures or joint penetration. In these cats, the pin was passed into the centre of the distal humeral canal. The concave nature of the olecranon fossa, which extends proximal to the level of the supratrochlear foramen, is not appreciated radiographically and this further compromises the width of the IM canal in the distal cat humerus and limits how far distal the IM pin can be placed. Fracture stability may be compromised when the pin cannot be seated in the distal bone and in this situation an auxiliary method of fixation, such as an ESF with a transcondylar pin, or an alternative method of fracture fixation, such as plate and screw fixation, should be selected.

Conclusion

When using the ESF and / or IM pins in the feline humerus, consideration of the anatomy in this area is imperative in order to avoid iatrogenic damage. Several conclusions can be made from the results of the study (Fig. 4).

There are no safe corridors for ESF pin insertion but hazardous corridors (also known as safe areas) exist in the proximal humerus bordered by the omotransversarius and insertion of the supraspinatus dorsally, the deltoideus caudolaterally and the cleidobrachialis craniolaterally. The safe area ends in a 'V' approximately one third of the way down the humerus where the acromial head of the deltoideus meets the cleidobrachialis. A distal safe area is present in the region of the lateral epicondyle.

When placing an ESF pin in the distal humerus it should be angled in a distolateral to proximomedial direction so that it penetrates the bone at least 20 mm proximal to the medial epicondyle avoiding the supracondylar foramen medially and the radial nerve laterally.

When placing pins in a transcondylar fashion, a pin of between 1.5 mm and 2.2 mm diameter should be used. The pins should be angled from just cranial to the lateral epicondyle to exit the bone craniodistal to the medial epicondyle.

If passage of an IM pin into the medial condyle of the humerus is required, confirmation that this can be achieved should be gained by assessing the size of the intramedullary canal radiographically in this region. A pin of not greater than 1.6 mm in diameter should be used.

In the majority of cats where passage into the medial condyle is not possible, the most distal safe seat is located in the supracondylar region level to the supracondylar foramen. If this short IM pin is not adequate, an auxiliary method should be employed, such as ESF, or an alternative fixation method selected.

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Correspondence to:
Sorrel J. Langley-Hobbs, BvetMed. DSAS, Dip ECVS, MRCVS
The Department of Veterinary Medicine
University of Cambridge
Madingley Road
Cambridge, CB3 OES, U.K.
Phone: +44 1223 337653, Fax: +44 1223 330848
E-mail: SJL41@cam.ac.uk

BOOKREVIEWS

Todd R. Tams

Small Animal Endoscopy

2nd Edition
488 pp
Mosby, 1999

This text provides a comprehensive review of endoscopic techniques in canine, feline and avian species. It has been expanded from the 1st edition, but remains geared towards both the practicing veterinarian and specialist. The text contains 1130 illustrations, including 880 colour images, which demonstrate normal appearances and a wide range of disease states visualized endoscopically.

The book is organized into chapters, which logically begins with an overview of endoscopic instrumentation and maintenance. These chapters deal with specifics that are useful for those considering purchasing an endoscope, and provide details that will utilize current endoscopes to their full potential. The next several chapters deal with gastrointestinal endoscopy, including oesophagoscopy, gastroscopy, enteroscopy, and colonoscopy. Also discussed are the endoscopic removal of gastrointestinal foreign bodies, placement of gastrostomy and jejunostomy tubes, and histopathological considerations. Patient preparation, endoscope manipulation, sampling techniques and the basics of endoscopic evaluation are succinctly covered, along with numerous images for each section. Endoscopy of the upper and lower respiratory tracts, and lower urinary tract, is covered in similar detail. Chapters on laparoscopy, arthroscopy and thoracoscopy cover instrumentation, techniques, sampling, complications and provide a basic understanding of these fields. Chapters on the rapidly expanding area of endoscopy in birds, reptiles and nondomestic species are included.

The biggest strength of this book is the vast array of excellent-quality images that give examples of normal and abnormal endoscopic appearances. In addition, there are ample descriptions to compliment the images and cover aspects of endoscopy in a reader-friendly format. This book provides the basics needed for the beginner endoscopist whilst also providing a comprehensive overview of diseases that will be useful to even the most experienced endoscopist.