Frontal sinus depth at four landmarks in breeds of dog typically affected by sinonasal aspergillosis

R. Burrow, D. McCarroll, M. Baker, P. Darby, F. McConnell, P. Cripps

The objective of this study was to assess whether the frontal sinuses in dogs with aspergillosis and of breeds typically affected by this condition were deeper at a more caudal location. CT scans of the head performed at the Small Animal Teaching Hospital, University of Liverpool, between April 2007 and March 2009 for dogs diagnosed with aspergillosis (group 1) and unaffected dogs of similar breeds (group 2) were selected for study. Sinus depth was measured at four standardised locations from reconstructed images of these CT scans. Data were compared for differences in sinus depth between groups and between landmarks. No significant difference was found between measurements within individual dogs or for each of the various landmarks between groups. Difference in depth of the sinuses between landmarks was significant (P<0.001). Sinus depth was significantly greater at the more caudal landmarks and was shallowest at the previously recommended landmark for sinus entry. In 54 per cent of dogs, the frontal sinus depth measured less than or equal to 2 cm at one or more of the landmarks. Sinus entry at the deepest point will reduce the risk of accidentally damaging underlying structures. This may be approximately 1 cm caudal, in breeds of dog that typically develop aspergillosis, to a previously suggested landmark.

NASAL aspergillosis is the second most common cause of chronic nasal discharge in dogs, accounting for approximately 7 to 34 per cent of dogs with nasal disease (Lane and Wärncke 1977, Harvey and O’Brien 1983, Sullivan 1987, Tasker and others 1999, Meier and others 2008). The disease is associated with a high morbidity (Lane and others 1974, Sharp and others 1984, 1991) causing osteomyelitis and progressive destruction of the paranasal sinuses, turbinates, nasal bones and cribriform plate with extension into the periorbital soft tissues or brain (Parker and Cunningham 1971, Soltys and Sumner-Smith 1971, Cadwallader and others 1973, Lane and others 1974, Harvey and O’Brien 1983, Sharp and others 1991, Davidson and Pappagianis 1995, Zonderland and others 2002). Common clinical signs include sneezing, mucopurulent nasal discharge, epistaxis, degloving and/or ulceration of the external nares, pain or discomfort of the facial region, lethargy and anappetence (Sharp and others 1991). Dolichocephalic and mesaticephalic breeds such as golden retrievers and border collies are most commonly affected. Treatment options include systemic antifungal drugs, topical antifungal drugs administered by catheters ‘non-invasively’ placed via the nasal cavity and ‘invasive’ administration of antifungal drugs by means of direct surgical entry of the frontal sinuses. The use of systemic antifungal drugs avoids surgery but requires prolonged courses to be efficacious. Consequently, these treatments are expensive, and they may result in adverse effects such as hepatotoxicity, vomiting and anorexia (Harvey 1984, Sharp and Sullivan 1989, Sharp and others 1991, Legendre 1995, Schochet and Lappin 2005). Topical treatments have a much greater success rate than systemic treatments (Sharp and others 1993, Davidson and Pappagianis 1995, Bray and others 1998, McCullough and others 1998, Smith and others 1998, Friend and others 2002, Zonderland and others 2002, Sissener and others 2006): enilconazole has had a reported success of 90 per cent (Sharp and others 1993). One study in particular compared clotrimazole administered by means of surgical trephination and non-invasive instillation using catheters and concluded that either methods were effective (Mathews and others 1998). Several sites for trephination of the frontal sinus in dogs have been briefly described in the veterinary literature. Barrett and others (1977) described trephination of the frontal sinuses 2 mm from the midline along a line joining the supraorbital processes. Holt (1998) and Matthews (2004) recommend trephination at a point midway between the midline and the zygomatic process of the frontal bone along a line joining the zygomatic processes. Sharp and others (1991) recommend trephination in the centre of an imaginary triangle formed with its base along the midline of the skull with the other landmarks being the frontal crest and the bony rim of the orbit. Benitah (2006) described trephination of the frontal sinus using the landmarks of the...
or the medial-rostral landmark (b) is located along this line, 1 cm from the midline. The mid-caudal landmark (c) lies in the same sagittal plane as the mid-rostral landmark at a location 1 cm caudal to the latter; similarly, the medial-caudal landmark (d) lies 1 cm caudal to the medial-rostral landmark.

In this study, the authors measured the depth of the frontal sinus at a previously described point (Holt 1998, Matthews 2004) that is objective and repeatable and compared this measurement with the depth of the sinuses at three other locations in dogs with sinonasal aspergillosis and breeds of dog typically affected by aspergillosis. In a previous investigation of nasal disease, the authors’ impression that the frontal sinus might be slightly deeper at a more caudal landmark. The authors’ assumption is that entry of the sinus at a point where its depth is greatest will minimise the risk of penetration of the calvarium, one of the potentially most serious complications reported for this procedure. The aim of this study was to assess whether the frontal sinuses in dogs with aspergillosis and of breeds typically affected by this condition were deeper at a more caudal location. In addition, by measuring frontal sinus depth, the authors aimed to confirm the suggestion that a pin length of 1 to 2 cm for sinus entry would be suitable to avoid damage to the calvarium in dog breeds that are typically affected by aspergillosis.

Materials and methods
Case records of dogs undergoing a CT scan of the head at the Small Animal Teaching Hospital, University of Liverpool, between April 2007 and March 2009 were identified, and cases diagnosis with sinonasal aspergillosis, and cases undergoing a CT scan for radiotherapy planning, were selected for further investigation. Inclusion criteria for dogs diagnosed with sinonasal aspergillosis were complete case records and a CT scan of the head. A diagnosis of sinonasal aspergillosis was made with a combination of typical signalment, history and clinical examination, marked destructive changes seen on CT scan, turbinate destruction and/or fungal plaques seen at rhinoscopy and fungal hyphae in nasal biopsy specimens. Dogs were excluded if there was destruction of the frontal bones or calvarium. Exclusion criteria for cases undergoing CT for radiotherapy planning included nasal neoplasia and/or neoplasia destroying/distorting the bones of the skull and/or involving the frontal sinuses.

Dogs were divided into two groups—group 1: dogs with sinonasal aspergillosis and group 2: dogs without nasal disease undergoing a CT scan of the head for radiotherapy planning.

The CT scans were performed while the dogs were sedated and were the only procedure performed under sedation. Dogs undergoing investigation of nasal disease were anaesthetised on a separate, later occasion to undergo further investigative procedures.

Dogs were scanned using a four-slice helical CT scanner (Siemens Somatom Volume Zoom; Siemens) with the following scan parameters: 120 kVp, 100 effective mAs, 1 mm slice collimation, 3 mm table feed per rotation and 1 second rotation time. Data were acquired in the transverse plane.

Images were reconstructed with the following parameters: 1.25 mm slice width, 1.2 mm reconstruction increment, ultrasharp kernel, window width 4000 and window centre 700. This produced slightly overlapping images optimised for imaging of the bone.
Three-dimensional multiplanar reconstructions were used to produce images of the skull. Measurements were made using appropriate software (syngo). All measurements were made by one observer (DM). The depths of the right and left frontal sinuses were measured at four points, giving eight measurements per skull. The first point where measurements were made was midway between the midline and the zygomatic process along a line joining the zygomatic processes (mid-rostral). The second point for taking measurements was then made along the line joining the zygomatic processes but at a more medial location 1 cm from the midline (medial-rostral). The third and fourth points for taking measurements were located along a line that was parallel to the line joining the zygomatic processes and at a distance 1 cm caudal to the first and second points (mid-caudal and medial-caudal, respectively) (Fig 1). Reconstructed images of the skull were selected to make measurements of frontal sinus depth at the sagittal planes passing via the medial-caudal and medial-rostral and mid-caudal and mid-rostral points. To measure the frontal sinus depth at each of the points described above, a line was superimposed on the relevant sagittal CT image to demonstrate the path that a pin would follow if it entered the frontal sinus perpendicularly to the outer table of the frontal bone at that described entry point. The depth of the sinus at each location was measured as the distance along this line, from the inner surface of the outer table of the frontal bone to the outer surface of the inner table of the frontal bone (Fig 2).

The data were entered into an Excel spreadsheet (Microsoft) and analysed using Minitab 15 (Minitab) and Stata 11 (StataCorp). After standard basic descriptive statistics, sinus depth was investigated with the Stata’s xtmixed command for mixed-effects linear regression (ie, assuming a Gaussian distribution) and using maximum likelihood estimation. The effects of side (left or right), site (caudal or rostral) and relationship to the midline (‘position’, mid or medial) were explored together with their first-order interactions and the possible influence of age, weight and sex. Individual dog identity was included as a random effect, and models were compared with and without random intercepts for factor variables and a random slope for age and weight within dogs. Preliminary analyses showed a highly significant interaction between site and position (P<0.001), and the authors therefore included each combination separately (ie, medial-rostral, medial-caudal, mid-rostral and mid-caudal). The final model for estimates of the fixed effects was chosen based on changes in deviance, Wald statistics and changes in the Bayesian and Akaike information criteria. The validity of the model assumptions was confirmed by graphical checks of the residuals for normality and plots of residuals against fitted values, covariates and levels of factors. CI and estimated means were obtained using the ‘margins’ command using the default settings. A variable was deemed to be important enough to keep in the final model if its associated significance was P<0.10 and was deemed statistically significant at P<0.05.

Results

There were 14 dogs in group 1 (aspergillosis) with a mean (sd) age of eight (2.91) years (range: two to 13 years): seven male entire, five male neutered and two female neutered dogs. There were four German shepherd dogs (GSDs), four golden retrievers, two border collies, one English bull terrier, one Staffordshire bull terrier, one deerhound and one collie crossbreed. The bodyweight range was 17 to 52.4 kg, and the mean bodyweight was 31.9 kg. There were 12 dogs in group 2 (radiotherapy planning) with a mean (sd) age of 8.7 (3.37) years: two of the observers (one male entire, two male neutered, two female entire and five female neutered dogs. There were two GSDs, six golden retrievers and four border collies. The bodyweight range was 17 to 52.4 kg, and the mean bodyweight was 32.3 kg. No statistical difference was found between the ages and bodyweights of dogs in group 1 and 2 (P>0.05).

The frontal sinus measurements for dogs in group 1 and 2 are listed in Tables 1 and 2. No statistical difference was found in measurements at each of the corresponding points between group 1 and 2 dogs (P>0.05).

Results of the mixed-effects modelling

There was no significant effect of side of the head, that is, right compared with left (P=0.16). The final ‘best’ model included the site-side combination, age and weight with site-position combination and age included as random effects within the level of dog identity. Each unit increase in age was associated with a decrease in depth of 0.06 cm (95 per cent CI -0.110 to -0.010 cm, P=0.017), whereas one unit increase in weight resulted in a mean increase of 0.02 cm (95 per cent CI 0.005 to 0.037 cm, P=0.012). The site-position combinations were significantly different from each other (P<0.001) with estimated mean values shown in Table 3.

Notwithstanding these results, there was variation of the deepest and shallowest sites of the frontal sinuses between dogs, and within dogs, there were differences between left and right sides. When considering the mean values of left and right measurements combined for
The landmark described by Barrett and others (1977) was reproducible and objective, but in a pioneer cadaver study performed by the authors, it was found that trephination at this site often resulted in disruption of the midline septum, making the procedure more difficult and confusing when this occurred. For this reason, the authors chose to measure additional standardised sites 1 cm from the midline.

Each dog, the deepest site was as follows: medial-rostral in one dog, mid-rostral in two dogs, medial-caudal in five dogs and mid-caudal in 18 dogs. In two dogs, the mid-caudal location gave the deepest measurement on one side of the skull and the shallowest measurement on the other side.

In 7 of 14 (50 per cent) dogs in group 1 and in 7 of 12 (58 per cent) dogs in group 2 (or 14 of 26 (54 per cent) dogs in groups 1 and 2 combined), the frontal sinus was less than 2 cm in depth at one or more of the sites that were measured in this study. Frontal sinus depth ranged from 1.02 cm (measured at the mid-rostral location in a 31.9 kg GSD) to 4.06 cm (measured at the mid-caudal location in a 31.3 kg golden retriever).

### Discussion

This study demonstrated that the frontal sinuses in dog breeds typically affected by sinusonal aspergillosis were significantly deeper at the more caudal locations detailed in this study. Of the four locations measured in the current study, the frontal sinuses were actually shallowest at the landmark recommended for entry of the frontal sinus (termed mid-rostral in this study) by Holt (1998) and Matthews (2004). The difference in depth between the mean values for the deepest (mid-caudal) and shallowest (mid-rostral) locations was 6.5 mm. Considering this difference in an alternative way, the depth of the sinus at the more caudal location was 35 per cent greater than at the more rostral location. The authors would thus expect a reduced risk of penetration of the calvarium and underlying brain, a potentially devastating injury, by using the more caudal locations that were described in this study. This contradicts the suggestion of Matthews (2004) that there is a greater risk of penetration of the calvarium at a location caudal to the level of the zygomatic processes.

The authors chose to evaluate the landmarks described by Holt (1998) and Matthews (2004) because they are reproducible, standardised and objective. In this study, the points described by Sharp and others (1991) and Benitah (2006) were not assessed because these were more subjective (ie, the centre of a variably shaped triangle) and thus not considered repeatable landmarks for the purpose of this study, although clinically a point based on anatomy alone rather than measurement is useful. It suggests an approximate, repeatable site for trephination regardless of skull size.

The landmark described by Barrett and others (1977) was reproducible and objective, but in a pioneer cadaver study performed by the authors, it was found that trephination at this site often resulted in disruption of the midline septum, making the procedure more difficult and confusing when this occurred. For this reason, the authors chose to measure additional standardised sites 1 cm from the midline.

While this study was not made to assess the risk of penetration of the calvarium if the surgeon did not stop applying pressure on the pin and chuck immediately on passage of the pin via the frontal bone. Alternative methods of entering the frontal sinus that might reduce the risk of penetration of the calvarium include the use of a bur or trephine (Holt 1998) to remove a piece of frontal bone rather than to pierce it.

Further considerations for this study would be the effects of the compartmentalisation of the frontal sinus into the lateral, medial and rostral parts (Evans and Christensen 1979). Each compartment is separate and drains into the nasal cavity through unique ostia that do not communicate with each other, and the lateral compartment is the largest. This has implications for the treatment of aspergillosis by sinus trephination because if the frontal sinus compartments are intact, antifungal drug will only be deposited in one compartment on each side, leaving the other areas untreated. As anticipated, the individual variation in anatomy, head size and conformation meant that the actual compartment entered in our cases was variable. Aspergillosis may result in destruction of the septae between sinus compartments, facilitating distribution of topical antifungal drugs. The authors could not assess whether the septae were intact in the skulls of dogs examined by CT.

### Table 3: Mean, upper and lower 95% CI of sinus depth at each of the four locations measured for group 1 and 2 dogs combined

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean sinus depth (cm)</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial-caudal</td>
<td>2.55</td>
<td>2.39</td>
<td>2.72</td>
</tr>
<tr>
<td>Medial-rostral</td>
<td>2.27</td>
<td>2.10</td>
<td>2.44</td>
</tr>
<tr>
<td>Mid-caudal</td>
<td>2.76</td>
<td>2.58</td>
<td>2.94</td>
</tr>
<tr>
<td>Mid-rostral</td>
<td>2.11</td>
<td>1.92</td>
<td>2.31</td>
</tr>
</tbody>
</table>
scans in this study, but this would be interesting for further study and might support intraoperative attempts to breakdown these septae if they are intact. This study does have limitations. The number of cases studied was low; more CT scans for these breeds and other breeds would be necessary to confirm that the findings of this study are not a result of random variation.

This study assessed frontal sinus depth measurements from a CT scan; the actual site of trephination of the frontal sinus in an animal is likely to be much more variable than the intended site because palpation of the landmarks may be inexact because of covering tissues, etc. In this study, all measurements were made in the sagittal plane along a line entering the frontal bone perpendicularly. Assuming that the pin will take this path allows standardised measurements of frontal sinus to be made. Although this assumption is acceptable for the purposes of the study, it cannot be assumed that this is the path that the pin will always take in patients. In practice, it is likely that the pin will not always be introduced at an angle that is perpendicular to the frontal bone or along the true sagittal plane. Changing the orientation of entry would therefore alter the effective frontal sinus depth at that level and could result in damage to local structures, such as the ethmoturbines, other than the cranium. However, the authors consider that the results of this study do emphasise the care and consideration that veterinary surgeons should take when using this surgical technique to gain access to the frontal sinus.

In conclusion, this study does demonstrate that in the typical dog breeds affected by aspergillosis, the frontal sinus is deeper at the more caudally described landmarks in the majority of dogs that were evaluated so that entry into the frontal sinus at a slightly more caudal location to the one currently recommended may reduce the risk of damage to the calvarium and/or ethmoturbines. As anticipated, there was considerable variability and asymmetry between and within individual dogs, and this should be considered when performing surgery on the frontal sinuses regardless of the landmark used. The authors suggest that a Steinman pin of maximum 1 cm length should be used to avoid inadvertent penetration of the underlying calvarium; alternative techniques using a bone bur or trephine may be safer in atypical and smaller breeds.

References
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