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TURBINATE ATROPHY EVALUATION IN PIGS BY COMPUTED TOMOGRAPHY

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Computed tomography (CT), a non-invasive visualisation technique was applied for imaging the bony structures of the nasal cavity of pigs, and compared to the traditional scoring system of turbinate atrophy in swine. Twenty-three 27-week-old pigs representing various stages of turbinate atrophy were used. Nasal structures were visually scored on CT scans and transversal cuts of the noses at the level of the first upper premolar teeth using the same scoring system in both cases. A tissue/air area ratio was also determined based on density differences. A highly significant correlation was found between visual scoring of CT images and transversal cuts of pig noses ($r = 0.98$, $p < 0.0001$) as well as between visual scoring of CT images and tissue/air area ratio determination ($r = -0.82$, $p < 0.0001$).

Key words: Atrophic rhinitis, swine, turbinate atrophy, computed tomography

Atrophic rhinitis (AR) is an important, widely prevalent infectious disease of swine (Rutter, 1985). The main pathognomonic clinical sign of the condition is facial distortion because of disturbances in physiological nasal bone development. When the disturbance of bone growth affects one side of the face more than the other, lateral deviation of the snout takes place. This facial deformity results from an underlying atrophy of the nasal turbinate bones, which is the most characteristic pathological lesion of AR.

Traditionally, the extension of turbinate atrophy is assessed by transverse section of the nasal cavity at the level of the first/second upper premolar teeth where the dorsal and ventral conchae are maximally developed in the healthy pig. In mild to moderate cases the ventral scrolls of the turbinates are the most commonly affected area: they vary from slightly shrunken to complete atrophy.

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In more severe cases, atrophy of the dorsal scrolls of the ventral turbinate and the dorsal and ethmoidal turbinates can be observed. In the most severe form there is a complete absence of all turbinate structures. Nasal septum deviation (NSD) is also often observed. However, slaughter evaluation has the disadvantage of allowing only one examination of the same animal.

Early attempts to detect turbinate atrophy *in vivo* applied radiography (Schöss and Siggel, 1973; Done, 1976; Eikelenboom et al., 1978; Plonait et al., 1980) or rhinoscopy (Plonait et al., 1980), however, they showed only limited value in conducting long-term studies with young pigs or evaluating mild forms of atrophic rhinitis (Schöss, 1983). Recently, computed tomography (CT) was successfully used for imaging the bony structures of the nasal cavity of pigs (Jolie et al., 1990; Shryock et al., 1998). CT, a non-invasive imaging technique seems suitable to detect even slight turbinate damages in the live animal, and so could be a useful tool for long-term follow-up the pathological events of AR.

In the present report, evaluation of CT images was compared to the traditional scoring system of turbinate atrophy.

Materials and methods

Animals

Altogether 23 pigs of the Hungarian Large White breed were used in the study. The pigs were selected from an AR efficacy study, including the controls to represent various stages of turbinate atrophy. Pigs were at the age of 27 weeks when subjected to CT examination. Then all pigs were slaughtered and macroscopic nasal lesions were evaluated.

Computer tomography

To immobilise the pigs for the scanning procedure, 4 mg/kg azaperone (Stresnil, Janssen Pharmaceutica) was administered intramuscularly for sedation and 9 mg/kg ketamine hydrochloride (SBH-Ketamin inj., SelBruHa) was administered intravenously to anaesthetise the pigs.

The anaesthetised pigs were fixed in stretched position, lying flat in a purpose-designed container during the CT examination. CT images from each pig were acquired using a Somatom Plus 40 (Siemens) third-generation scanner. The starting position of the scanning was set approximately 10 mm anterior from the level of the first upper premolar teeth, and then consecutive three-mm scans were taken with a table feed of five mm. The imaging protocol was a so-called ‘high’ algorithm, which is extremely sensitive in visualising tissues of high-density differences. Zoom factor was set to 3.5.

Evaluation of CT images

Two approaches were applied to quantify nasal lesions: a visual scoring of the nasal architecture and a morphometric analysis of the region of interest on the CT images.

Visual scoring of the nasal structures was done on CT scans at the level of the first premolar teeth. The scoring system was the same as used at the post-mortem evaluation of nasal lesions.

Besides visual scoring of CT images, a tissue/air area ratio was also established based on density differences. The same image was used as for visual scoring. Area determination was performed in two steps. First the total air area (cm^2) inside the nasal cavity was determined (Fig. 1b); areas belonging to –1000–(–)200 values on the Hounsfield (HU) scale. Then the tissue area (cm^2) of the ventral nasal turbinates having a density between HU 200–1000 was measured (Fig. 1a). The ratio of the above-mentioned values was computed in both the left and the right sides. Finally, a total tissue/air ratio was calculated. Area determination and ratio calculation were performed with a computer program developed by the Institute of Diagnostic Imaging and Radiation Oncology (Kaposvár, Hungary).

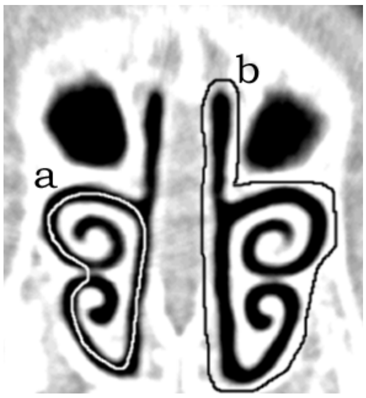

Fig. 1. Determination of tissue/air area ratio

Nasal lesion scoring

The nose was cut transversally at the level of the first upper premolar teeth. Each of the four scrolls of the ventral turbinate bones was scored according to the following criteria (TA score): 0, no lesion; 1, a small part of the turbinate bone (nearly half a scroll) is absent; 2, slight atrophy – more than half a scroll is absent; 3, moderate atrophy – the turbinate bone is straightened; 4, severe atrophy – total disappearance of the turbinate bone. NSD was scored on a scale of 0–2: 0, normal; 1, slight deviation; 2, severe deviation. TA and NSD scores were summed for each individual to a maximum value of 18.

Statistical analysis

Statistical analysis was carried out with Spearman correlation using SPSS 10 for Windows (1999).

Results and discussion

Table 1 summarises the results achieved by various nasal lesion evaluation methods. Visual nasal lesion scores clearly indicate that the selected pig population represented the full range of turbinate bone conditions from normal healthy nose to complete loss of bony architecture in the nasal cavity.

Table 1

Visual nasal lesion scores and tissue/air area ratio values of 27-week-old pigs. Pigs are listed in ascendant order of their visual nasal lesion scores determined at slaughter evaluation of turbinate atrophy

Pig No.	Nasal lesion score			Area ratio
	SL	CT	CT*	
64	0	0	0	0.32
145	0	1	1	0.27
150	0	0	0	0.21
247	0	1	1	0.24
130	1	0	0	0.36
82	3	5	4	0.34
142	3	2	2	0.19
206	3	2	2	0.18
63	4	4	4	0.05
45	5	6	6	0.17
128	5	5	4	0.27
243	5	5	4	0.17
46	6	7	6	0.28
70	7	7	5	0.09
50	8	8	8	0.13
121	8	7	5	0.12
164	12	12	10	0.05
187	15	13	12	0.02
262	17	16	16	0.00
87	18	17	16	0.00
89	18	16	16	0.00
186	18	18	16	0.00
266	18	17	16	0.04

SL = slaughter evaluation; CT = computed tomography; *Scores without nasal septum deviation

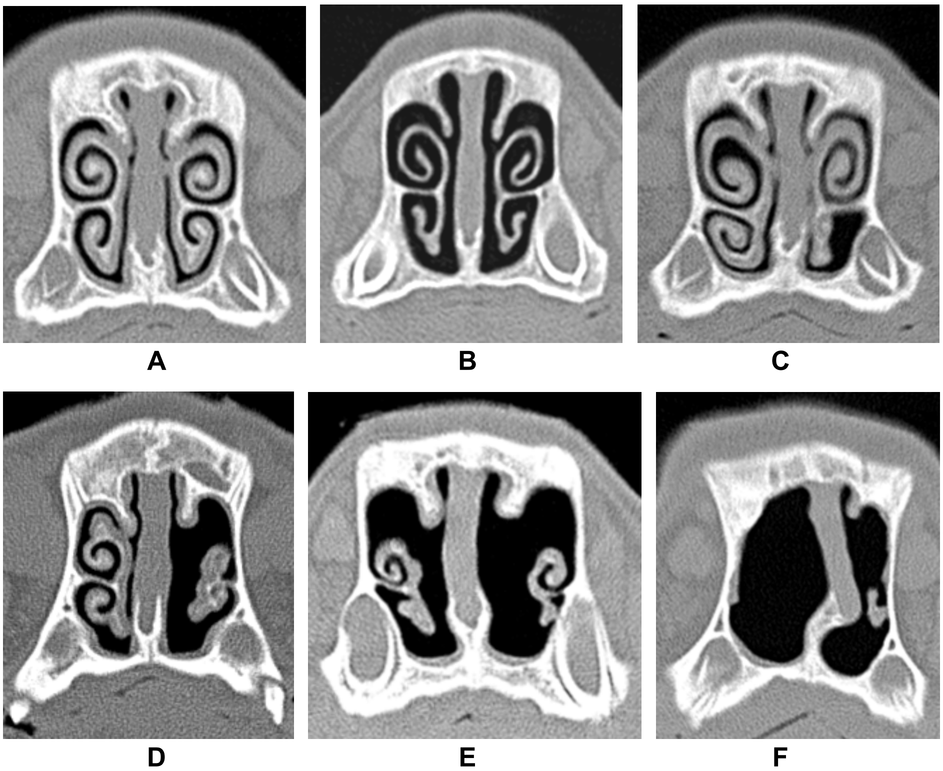

Fig. 2A. Pig No. 64: normal anatomy of nasal structures

Fig. 2B. Pig No. 63: the number and length of ventral turbinate scrolls are retained but the tissue of both the dorsal and the ventral turbinates have become remarkably thin

Fig. 2C. Pig No. 243: mild atrophy of the dorsal scroll of the left ventral turbinate, remarkable atrophy of the ventral scroll of the right ventral turbinate, and slight deviation of the nasal septum

Fig. 2D. Pig No. 50: mild atrophy of the left ventral turbinate, severe atrophy of the right ventral turbinate, the nasal septum is normal

Fig. 2E. Pig No. 187: severe atrophy of both ventral turbinates, the ventral scroll of the right ventral turbinate has disappeared, slight deviation of the nasal septum

Fig. 2F. Pig No 186: complete absence of all turbinate structures accompanied with severe lateral deviation of the nasal septum

Figure 2 shows CT scans of nasal cavities of pigs presenting examples of normal nasal structure (Fig. 2A) and turbinate atrophy of various degrees (Fig. 2B–F). The resolution of the pictures improved, compared to their quality in former publications (Jolie et al., 1990; Shryock et al., 1998), most probably due to the continuous development of CT scanners and image processing procedures. The higher resolution provides more detailed images, which may help to get a better understanding of the morphological changes during the pathogenesis of AR. A good example is given in Fig. 2B. It shows the nasal cavity of a pig where the number and length of ventral turbinate scrolls are retained but the tissue of both the dorsal and the ventral turbinates have become remarkably thin. By gross pathology, this lesion appeared very mild and received a score of 4 (Table 1). Using the same judgement criteria (the number and length of turbinate scrolls), the same score was assigned by visual scoring of the CT images. At the same time, a discrepancy between visual scoring and tissue/air area ratio determination occurred in this case (Table 1). The tissue/air area ratio value placed this animal among pigs having the more pronounced loss of tissues in the nasal cavity. It is very probable that, although the surface of the turbinates remained normal, the changes in tissue structure must affect the function of the turbinates. It needs supplementary examinations to describe the histological level and clarify the importance of such a lesion.

A highly significant correlation was found when visual scoring of CT images and transversal cuts of pig noses were compared ($r = 0.98$, $p < 0.0001$). Results indicate that CT imaging is a powerful tool for non-invasive tracking of nasal lesions. The fact that no animal has to be killed for scoring and that animals can be examined repeatedly makes CT a superior method over postmortem evaluation of nasal lesions.

Also the visual scoring of CT images correlated well with tissue/air area ratio determination ($r = -0.82$, $p < 0.0001$). Area ratio determination is based on density differences on the CT picture and provides the opportunity for an objective quantification of structural changes in the nasal cavity instead of scoring. However, the method has at least one major disadvantage. The value is not influenced by nasal septum deviation since the deviated septum usually keeps its volume, i.e. on the pictures it covers the same area as in its normal shape. On the other hand, the volume of turbinate bones can be estimated from tissue/air area ratio on sequential nasal scans. Supplementing this information with that of septum deviation gives a full description of the status of the nasal cavity, without the need of sacrificing animal life.

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