Turk. J. Vet. Anim. Sci.
2010; 34(4): 339-347
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doi:10.3906/vet-0802-27

Research Article

Analysis of larynx measurements and proportions in young and adult domestic pigs (*Sus scropha domestica*)

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Received: 26.02.2008

Abstract: The aim of the present study was to examine differences in proportions of the larynx between young and adult domestic pigs. Larynges (17 piglets and 14 adults) were obtained from a slaughterhouse where pigs were routinely slaughtered. Anatomical preparation, observation, and description, as well as measurements performed using MULTISCAN image analysis, were used. In the statistical analysis, apart from the arithmetic mean ($\bar{x}$) and the standard deviation (SD), Student's t test was used with the statistical significance at $\alpha = 0.05$.

The results showed that a significant influence of sex was observed as far as proportions of the epiglottic cartilage (smaller in older individuals) and the arytenoid cartilage parameters (3b,c) were concerned. The influence of age was found in reference to coefficients determining distance between the back horns of the thyroid cartilage and the length of the front horn of the thyroid cartilage.

Key words: Larynx, anatomy, measurements, domestic pig, young, adult

Introduction

The anatomy of the larynx is characterized by considerable complexity of structure and functions, expressed by the small size and precision of fulfilled functions. Morphology of the larynx skeleton obviously determines the shape and the function of muscles, particularly voice folds, which are basic for larynx mechanics and phonation (1). In the last few years, a wide range of measurements characterizing the human larynx was gathered (2-8). A number of studies concerning functional and clinical larynx anatomy were also carried out on animals. These studies examined larynx re-innervation after experimentally evoked paralysis (4,9), structure of individual larynx structures (1,8,10-13), their innervations (5), and functions (14,15), as well as 3-dimensional modeling of larynx anatomy (16).

There are no studies available in the literature concerning the anatomy of the animal larynx during the developmental period. The structure of the animal larynx, described precisely in morphological range, has not been researched sufficiently as far as size parameters are concerned (17-19). In particular, it is not known if changes in larynx anatomy happening during maturing, typical for humans and leading to the phenomenon known as mutation, also occur among animals.

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Materials and methods

The research was conducted on 31 porcine larynges (17 minors and 14 adults). The piglets were from 12 to 18 weeks old, while the boars and sows were old breeding animals. The larynges used for the study were taken from a slaughterhouse where pigs were routinely slaughtered. Therefore, the approval of the Bioethical Commission was not needed.

After collection the larynges were fixed in a 10% solution of formaldehyde for 6 weeks; then they were prepared using a standard set of microsurgical instruments. The methodology involved morphological observations and a range of linear, angular, and surface measurements.

The measurements were performed using MULTISCAN image analysis. In connection with some preparation difficulties concerning the cricoid and thyroid cartilage cracking, it was established that measurements of even surfaces would be done only on the left side.

After calculating the descriptive statistics, the differences between the groups were tested using Student's t-test with the statistical significance at $\alpha = 0.05$. The averages differed significantly when $|t_{emp}|>t_{\alpha,\upsilon}$; $t_{0.05, 15}= 2.131$ and $|t_{emp}|>t_{\alpha,\upsilon}$; $t_{0.05; 12} = 2.179$. The studied basic parameters are shown below in Figures 1-4.

In the anatomical description an official English veterinary nomenclature was used (20).

They were:

1. The thyroid cartilage
   a. craniocaudal dimension of the plate in a medial line
   b. distance between back horns
   c. maximum width
   d. maximum height
   e. length of the back horn
   f. maximum craniocaudal dimension
   g. angle between the plates
2. The cricoid cartilage
   a. width of the cricoid cartilage at the central point of the cricoarytenoid joint capsule

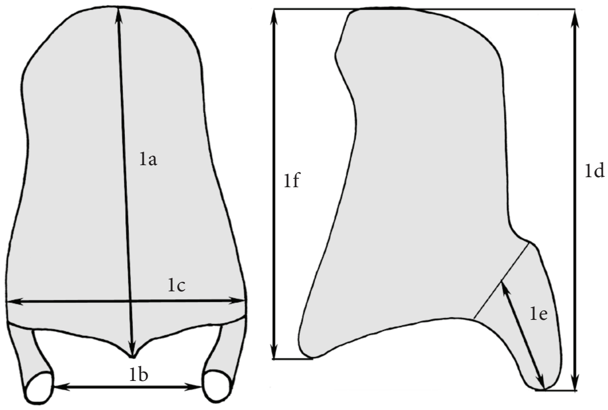

Figure 1. The thyroid cartilage measurement scheme.

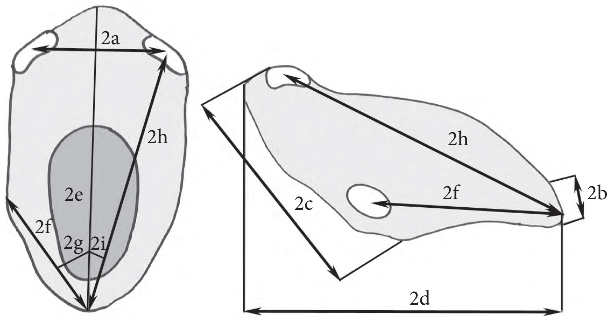

Figure 2. The cricoid cartilage measurement scheme.

   b. craniocaudal dimension of the arch in a medial line
   c. craniocaudal dimension of the plate in a medial line
   d. external fibular dimension measured at the edge of caudal cartilage
   e. surface of the internal contour (lumen) of the cricoid cartilage
   f. distance between the central point of the cricothyroid joint capsule and the ventral pole of the cricoid cartilage in a medial line
   g. the angle created by the above line with the fibular plane
   h. distance between the central point of the cricoarytenoid joint capsule and the ventral pole of the cricoid cartilage in a medial line
   i. the angle created by the above line with the fibular plane

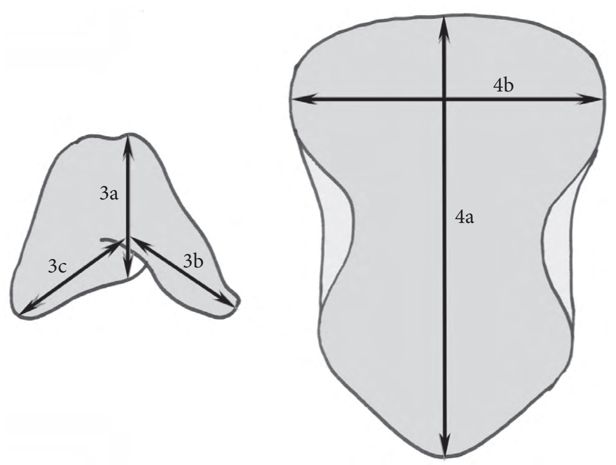

Figure 3. The arytenoid cartilage measurement scheme (left side) and the epiglottic cartilage measurement scheme (right side).

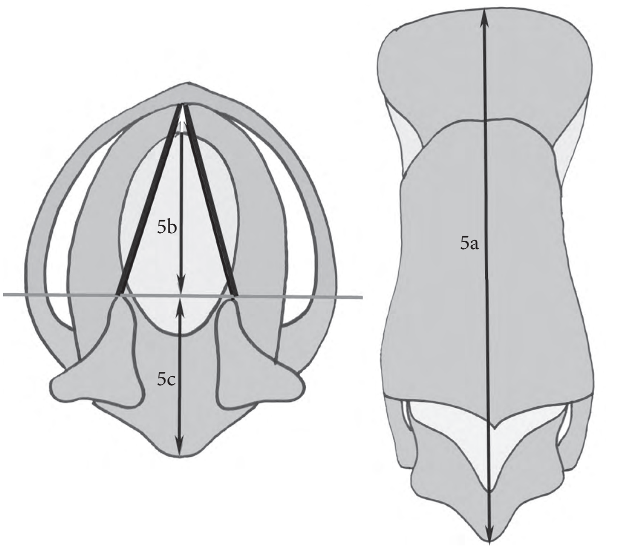

Figure 4. Whole larynx measurement scheme.

3. The arytenoid cartilage
   a. total height measured from the base to the top
   b. distance between the top of the vocal process and the center of the cricoid capsule
   c. distance between the top of the muscular process and the center of the cricoid capsule
4. The epiglottic cartilage
   a. maximum height
   b. maximum width
5. Larynx dimensions
   a. craniocaudal dimension of the whole larynx (from the top of the epiglottic cartilage to the lower edge of the cricoid cartilage)
   b. length of the membranous part of the true glottis
   c. length of the intercartilaginous part of the true glottis

All the parameters listed above are shown in Figures 1-4.

On the basis of initial size parameters indicators characterizing the proportions of larynx and useful for interspecies comparison were calculated. The list of indicators is shown in Table 1.

Results

The porcine thyroid cartilage (cartilago thyroidea) is characterized by considerable smoothness and lack of front horns (cornu anterius), front and back thyroid incisures (incisura thyroidea anterior et posterior). The oblique line (linea obliqua) is practically absent (Figures 5 and 6). The cricoid cartilage plate (lamina cartilaginis cricoidei) is high and it has a distinct, high, and sharp ridge on its back surface. Joint areas occur at the edge of the plate and the arch: convex, ellipsoidal arytenoid joint area (facies articularis arytenoidea) and round, concave thyroid joint area (facies articularis thyroidea). The arytenoid cartilage (cartilago arytenoidea) accretes with the corniculate one (cartilago corniculata). The interarytenoid cartilage (cartilago interarytenoidea) adheres to both arytenoid cartilages on the medial side. It leads to the formation of a complex made of 3 cartilages, which are difficult to separate without destroying any of them. This connection also seems to be the cause of limited mobility of the porcine arytenoid cartilages (Figure 7). The presence of the interarytenoid cartilage lessens the disproportion between quite low arytenoid cartilage and high and well-developed epiglottic cartilage (cartilago epiglottica). Therefore, the aryepiglottic fold (plica ary-epiglottica) is quite short (Figure 5). In fact, it should be called ‘interaryepiglottic fold’ in pigs, because the arytenoid cartilages do not take part in its creation. The

Table 1. Indicators characterizing individual proportions of larynx structures.

Successive parameter	Way of calculating	Description
		The thyroid cartilage
1	1e/1d	height of the back horn to total height of the thyroid cartilage
2	1d/1c	height of the thyroid cartilage to its width
3	1d/5a	height of the thyroid cartilage to the height of the whole larynx
		The cricoid cartilage
4	2c/2d	height of the plate to fibular dimension of the cricoid cartilage
5	2b/2d	height of the arch to fibular dimension of the cricoid cartilage
6	2f/2d	distance of the surface of the cricoid joint from the arch to fibular dimension of the cricoid cartilage
7	2h/2d	distance of the surface of the arytenoid joint from the arch to fibular dimension of the cricoid cartilage
8	2c/5a	height of the plate to height of the whole larynx
9	2a/2d	width of the cricoid cartilage to its fibular dimension
		The arytenoid cartilage
10	3b/3a	length of the vocal process to height of the arytenoid cartilage
11	3c/3a	length of the muscle process to height of the arytenoid cartilage
12	3a/5a	height of the arytenoid cartilage to height of the whole larynx
		The epiglottic cartilage
13	4a/4b	height of the epiglottic cartilage to its width
14	4a/5a	height of the epiglottic cartilage to height of the whole larynx
		The true glottis
15	5b/5c	the relation of the membranous part of the true glottis to the intercartilaginous part of the true glottis

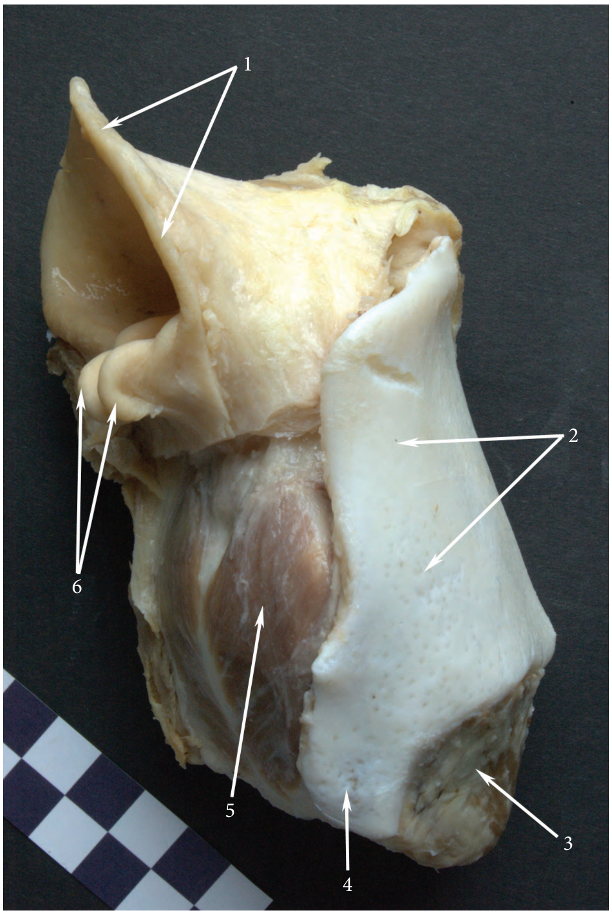

Figure 5. Adult boar larynx. Right and spine side. Centimetre measure. Marking: 1. free side of the epiglottis, 2. the plate of the thyroid cartilage, 3. right cricothyroid muscle, 4. back horn of the thyroid cartilage, 5. right back cricothyroid muscle, 6. the arytenoid cartilage.

Figure 6. The thyroid cartilage of a boar. Marking: 1. plate, 2. back horn.

interarytenoid cartilage is made of resilient, quite brittle, and fragile cartilage. It consists of an odd part, formed in the shape of 2 cylinders placed in the fibular plate with a shallow fissure between them and 2 limbs running backwards and accreting with crescent processes of the arytenoid cartilages (Figure 8). The epiglottic cartilage is of considerable size; it has a tubular shape with the front end curved outside. It is also characterized by the lack of an evident apex. The pedicle is short and rounded. The results of the chosen size parameters of larynx are shown in Table 2. The results of calculations of the chosen size indicators of larynx are shown in Table 3.

Discussion

The observations made during the present study are mostly consistent with textbook descriptions of porcine larynx (21). The larynx of a pig is characterized by an elongated, pipe-convoluted epiglottis and a very elongated thyroid cartilage with a wide plate lacking the front horn. The oblique line can only be seen in the vicinity of the back horn (12,21). The corniculate cartilages accrete with the arytenoid cartilages as their corniculate processes and they are bound upward and inward. Left- and right-side processes accrete with each other and they are refilled with falciform outgrowth. There is an inter-

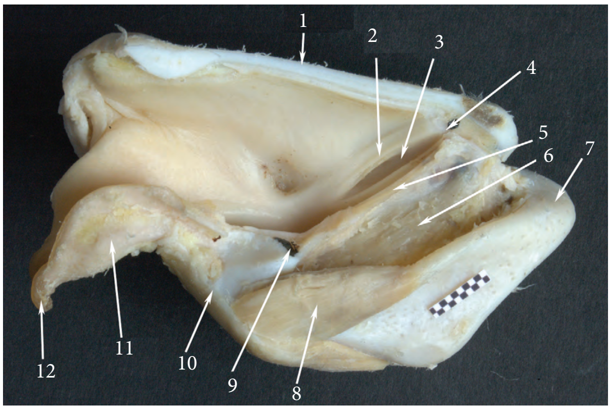

Figure 7. Larynx preparation of a boar. Right side view. Right plate of the thyroid cartilage has been removed to show the larynx cavity. Centimetre measure. Marking: 1. symphysis of the plates of the thyroid cartilage, 2. left atrial fold, 3. left larynx pouch, 4. symphysis of the vocal cords, 5. right vocal fold, 6. cricothyroarytenoid ligament, 7. the arch of the cricoid cartilage, 8. right side cricoarytenoid muscle, 9. vocal process of the right arythenoid cartilage, 10. muscle process, 11. the crescent cartilage, 12. the interarytenoid cartilage.

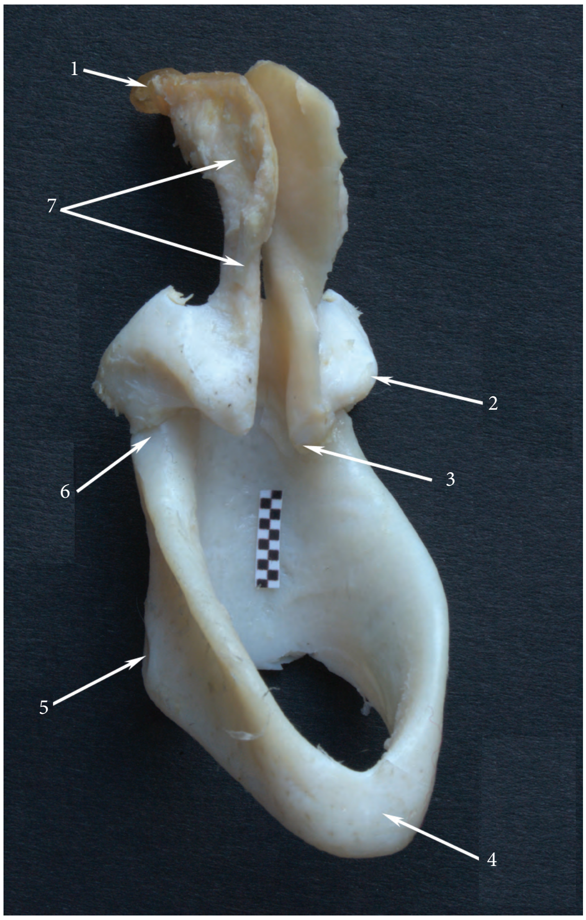

Figure 8. The preparation of separated cartilages of a boar. Right-front view. Centemetre measure. Marking: 1. medial part of the interarytenoid cartilage, 2. muscle process of the left arytenoid cartilage, 3. vocal process, 4. the cricoid cartilage arch, 5. the right thyroid joint area, 6. fragment of the right arytenoid joint area, 7. the right crescent cartilage and side part of the interarytenoid cartilage.

arytenoid cartilage between arytenoid cartilages, which closes the arytenoid area completely. The pig's arytenoid cartilage has long vocal process and strong but shorter muscle process. In fact, the arytenoid cartilages, the crescent cartilages, and the inter-arytenoid cartilage form one complex, which is not mentioned by other authors.

The length of the pig vocal fold, according to other authors, is about 21 mm (12), which refers rather to young individuals, because according to our studies the adult vocal fold is much bigger (compare with parameter 5 b in Table 2).

No significant influence of sex on the examined basic size parameters of larynx was shown, which means that this porcine organ is not characterized by sexual dimorphism.

The analysis of the data included in the tables showed a significant influence of age with reference to the indicator of distance of the arytenoid cartilage joint area from the arch in relation to the fibular dimension of the cricoid cartilage, the length of the muscle process in relation to the height of the arytenoid cartilage and the height of the arytenoid cartilage in relation to the size of the whole larynx (statistical significance at $\alpha = 0.05$).

There is significant dependence of the proportions of the larynx on the age of the individual but not on sex. There is no evidence of any sexual dimorphism of the pig larynx.

Table 2. The results of the measurements of the selected size parameters of porcine larynges. The results in relation to parameters 1i, 2g and 2i are in %, 2e in mm^2, the rest in mm.

Parameter	Minors n = 17									Adult n = 14								
	Males n=7				Females n = 10					Males n = 7				Females n = 7				
	$\overline{X}$	SD	min	max	$\overline{X}$	SD	min	max	t_{emp}	$\overline{X}$	SD	min	max	$\overline{X}$	SD	min	max	t_{emp}
1a	59.63^{a}	9.81	40.21	70.28	61.73^{a}	3.88	55.35	67.76	0.618	82.26^{a}	8.37	72.35	94.56	79.15^{a}	8.10	70.02	93.21	0.695
1b	30.01^{a}	4.12	22.38	35.67	31.98^{a}	2.69	28.70	36.61	0.198	46.04^{a}	2.66	41.78	48.34	46.08^{a}	3.80	41.34	52.36	0.028
1c	41.02^{a}	5.30	30.73	47.43	42.34^{a}	2.18	37.81	45.01	0.714	58.30^{a}	6.32	50.04	68.75	55.88^{b}	5.38	50.04	65.11	3.378
1d	61.55^{a}	8.05	47.23	70.11	62.82^{a}	4.05	56.36	69.83	0.431	81.25^{a}	7.28	72.50	90.20	78.76^{a}	6.20	72.34	86.86	0.639
1e	19.00^{a}	2.82	14.21	22.67	21.66^{a}	2.68	17.33	25.67	1. 972	28.29^{a}	2.32	24.72	31.45	27.13^{a}	2.84	22.34	30.61	0.935
1f	60.50^{a}	8.15	42.12	65.12	66.48^{a}	4.29	60.44	74.45	1.978	87.87^{a}	8.48	74.20	95.46	85.99^{b}	8.09	74.20	94.54	4.532
1g	76.59^{a}	3.67	71.76	81.08	74.63^{a}	7.39	62.77	85.12	0.644	80.58^{a}	2.69	77.65	84.67	80.32^{a}	3.17	76.95	84.60	1.438
2a	19.75^{a}	3.97	12.10	24.63	21.03^{a}	0.90	19.56	22.34	0.996	29.01^{a}	3.63	26.63	35.61	27.19^{a}	3.24	23.41	34.01	1.940
2b	9.96^{a}	2.69	6.17	13.34	10.46^{a}	1.18	8.79	12.34	0.525	13.54^{a}	1.49	11.23	15.73	12.42^{a}	1.27	11.17	14.06	1.406
2c	31.81^{a}	2.74	26.50	35.05	30.95^{a}	2.44	26.73	35.02	0.680	43.98^{a}	4.83	37.78	49.64	43.22^{a}	4.21	38.41	48.92	0.294
2d	48.83^{a}	4.25	42.30	54.21	53.49^{a}	6.37	45.46	61.78	0.683	71.45^{a}	4.42	62.51	76.20	69.89^{a}	4.10	62.51	76.20	0.660
2e	304.7^{a}	45.48	212.1	342.9	314.5^{a}	54.02	228.9	371.9	0.392	637.5^{a}	41.14	588.4	714.7	634.5^{a}	43.20	576.2	714.7	0.136
2f	30.38^{a}	4.06	25.26	36.12	32.76^{a}	5.36	24.28	38.78	0.989	45.39^{a}	5.40	33.25	48.36	43.81^{a}	4.92	33.25	48.10	0.547
2g	28.13^{a}	3.51	21.34	31.52	27.54^{a}	2.58	23.54	32.36	0.401	33.54^{a}	3.96	27.57	38.16	32.78^{a}	4.45	26.34	37.47	2.120
2h	47.31^{a}	4.22	38.17	51.37	52.84	4.12	46.10	58.12	2.697	66.58^{a}	6.82	54.30	74.36	62.88^{a}	6.49	53.27	71.23	1.015
2i	16.76^{a}	3.22	12.79	22.22	16.84^{a}	1.95	13.65	21.30	0.064	19.92^{a}	1.19	17.82	21.35	19.25^{a}	2.24	16.82	22.67	1.053
3a	12.25^{a}	1.22	10.45	14.23	12.67^{a}	2.25	9.30	15.67	0.447	15.14^{a}	1.75	11.60	16.80	14.60^{a}	1.66	11.60	16.80	0.577
3b	9.73^{a}	0.71	8.76	10.89	11.59^{b}	1.52	10.03	14.89	2.995	13.10^{a}	1.03	11.80	14.87	12.45^{a}	1.66	10.01	14.87	1.180
3c	5.82^{a}	0.94	4.12	7.01	7.65^{b}	0.97	6.10	9.10	3.876	11.39^{a}	1.61	10.02	14.43	10.84^{a}	1.13	10.02	13.20	0.639
4a	42.82^{a}	7.78	31.23	52.00	34.83^{b}	3.45	27.21	38.23	2.896	50.90^{a}	5.40	43.27	60.51	50.84^{a}	6.03	42.34	60.51	0.021
4b	36.89^{a}	6.49	30.11	48.23	37.67^{a}	3.49	32.67	42.45	0.322	50.71^{a}	7.81	33.50	57.26	49.59^{a}	7.47	33.50	57.26	0.268
5a	103.9^{a}	6.40	92.35	112.0	111.9^{a}	8.44	100.2	125.8	2.111	157.3^{a}	12.6	137.5	169.3	153.0^{a}	13.84	137.5	168.7	0.636
5b	23.88^{a}	4.87	14.10	29.34	25.83^{a}	2.06	20.72	28.36	1.140	42.09^{a}	6.79	34.18	54.15	41.54^{a}	7.94	32.30	54.15	0.151
5c	11.60^{a}	2.26	7.12	14.10	11.99^{a}	3.15	8.10	16.70	0.278	20.51^{a}	3.64	15.25	26.05	19.93^{a}	3.68	15.25	26.05	0.298
	$t_{0.05;\ 15} = 2.131$									$t_{0.05;\ 12} = 2.179$								

Table 3. The results of calculations of indicators characterizing proportions of porcine larynges grouped according to age and sex.

Successive indicator	Way of calculating	Minors n = 17									Adult n = 14								
		Males n = 7				Females n = 10					Males n = 7				Females n = 7				
		$\overline{X}$	SD	min	max	$\overline{X}$	SD	min	max	t_{emp}	$\overline{X}$	SD	min	max	$\overline{X}$	SD	min	max	t_{emp}
										The thyroid cartilage									
1	1e/1d	0.32[a]	0.03	0.26	0.35	0.33[a]	0.03	0.28	0.39	0.676	0.32[a]	0.03	0.29	0.38	0.32[a]	0.03	0.29	0.38	0
2	1d/1c	1.48[a]	0.10	1.34	1.58	1.57[a]	0.08	1.45	1.70	2.062	1.51[a]	0.11	1.39	1.68	1.54[a]	0.14	1.39	1.69	0.446
3	1d/5a	0.58[a]	0.06	0.46	0.63	0.60[a]	0.05	0.49	0.66	0.748	0.56[a]	0.03	0.53	0.62	0.56[a]	0.04	0.52	0.62	0
										The cricoid cartilage									
4	2c/2d	0.65[a]	0.06	0.59	0.79	0.59[a]	0.09	0.45	0.77	1.354	0.62[a]	0.06	0.52	0.69	0.62[a]	0.06	0.52	0.69	0
5	2b/2d	0.20[a]	0.04	0.15	0.27	0.20[a]	0.02	0.16	0.25	0	0.19[a]	0.01	0.18	0.22	0.18[a]	0.01	0.16	0.20	1.870
6	2f/2d	0.62[a]	0.07	0.49	0.72	0.61[a]	0.06	0.51	0.70	0.316	0.63[a]	0.05	0.53	0.69	0.63[a]	0.04	0.53	0.68	0
7	2h/2d	0.97[a]	0.07	0.89	1.10	0.99[a]	0.06	0.92	1.11	0.632	0.93[a]	0.05	0.87	1.01	0.90[a]	0.06	0.80	0.97	1.016
8	2c/5a	0.31[a]	0.02	0.28	0.34	0.28	0.03	0.23	0.33	2.301	0.28[a]	0.03	0.24	0.32	0.28[a]	0.03	0.24	0.32	0
9	2a/2d	0.40[a]	0.08	0.29	0.52	0.40[a]	0.04	0.34	0.45	0	0.41[a]	0.05	0.35	0.49	0.39[a]	0.05	0.34	0.48	0.748
										The arytenoid cartilage									
10	3b/3a	0.80[a]	0.05	0.73	0.86	0.94[a]	0.22	0.69	1.30	1.639	0.87[a]	0.10	0.76	1.02	0.86[a]	0.12	0.70	1.02	0.169
11	3c/3a	0.48[a]	0.07	0.39	0.60	0.62[b]	0.12	0.45	0.80	2.759	0.76[a]	0.13	0.62	0.98	0.75[a]	0.13	0.62	0.98	0.144
12	3a/5a	0.12[a]	0.01	0.11	0.14	0.11[a]	0.02	0.09	0.14	1.213	0.10[a]	0.01	0.08	0.12	0.10[a]	0.01	0.08	0.12	0
										The epiglottic cartilage									
13	4a/4b	1.18[a]	0.25	0.88	1.57	0.93[b]	0.08	0.79	1.06	2.987	1.02[a]	0.18	0.83	1.41	1.04[a]	0.18	0.84	1.41	0.208
14	4a/5a	0.41[a]	0.08	0.30	0.50	0.31[b]	0.02	0.27	0.33	3.834	0.32[a]	0.03	0.29	0.39	0.33[a]	0.04	0.29	0.40	0.529
										The true glottis									
15	5b/5c	2.07[a]	0.31	1.62	2.65	2.26	0.45	1.50	2.81	0.964	2.08[a]	0.33	1.66	2.60	2.11[a]	0.33	1.62	2.60	0.170
		$t_{0.05;\ 15} = 2.131$									$t_{0.05;\ 12} = 2.179$								

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