

Dimensions of the laryngeal framework in adults

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Summary. The increasing application of sophisticated electrophysiological, radiological and surgical methods to the diagnosis and treatment of laryngeal disorders requires a profound knowledge of the size and proportions of the human larynx and its cartilaginous components. Only inadequate data regarding this subject have so far been accessible. The larynges of 53 patients (28 male and 25 female, age 25-88 years, in the means 59 years) were removed during routine autopsy 12-48 h post mortem and immediately submitted to morphometric investigation. None of the patients had histories or visible signs of laryngeal disease. Anatomical preparations were performed with customary surgical tools and morphometric measurements then carried out with a pair of compasses and a calliper rule. A total of 95 measurements were performed on each larynx. These included, aside from evaluation of the whole organ, identification of the internal and external diameters of the cricoid cartilage, height and length of the thyroid alae in different planes, angle of thyroid laminae, height of arytenoid cartilage, width and length of epiglottic cartilage, and

internal and external diameter of first tracheal ring. The results obtained provide a full scale of data determining the size and extent not only of its cartilaginous components, but of the laryngeal framework as a whole. The knowledge of these data may contribute to a precise positioning of electrodes in laryngeal electromyography, to the planning of laryngeal framework surgery, and to the analysis of CT- and MRI-scans of the larynx.

Dimensions des structures laryngées de l'adulte

Résumé. Les applications croissantes des méthodes électrophysiologiques, radiologiques et chirurgicales sophistiquées pour le diagnostic et le traitement de troubles laryngés nécessite une connaissance approfondie de la taille et des proportions du larynx humain et de ses composants cartilagineux. Seules des données inadéquates concernant ce sujet sont accessibles. Le larynx de 53 sujets (28 hommes et 25 femmes, âgés de 25 à 88 ans, avec une moyenne de 59 ans) ont été prélevés durant des autopsies habituelles 12 à 48 h post mortem et immédiatement soumis à des investigations morphométriques. Aucun de ces patients n'avait d'histoire ou de signe visible de maladie laryngée.

Les préparations anatomiques ont été réalisées avec des instruments chirurgicaux habituels, et les mesures morphométriques ont été faites à l'aide de compas et d'une règle graduée. Un total de 95 mesures a été réalisé sur chaque larynx. Celles-ci incluent, à côté de l'évaluation de l'ensemble de l'organe, l'identification des diamètres interne et externe du cartilage cricoïde, de la hauteur et de la longueur des ailes thyroïdiennes dans les différents plans, l'angle des lames thyroïdiennes, de la hauteur du cartilage aryénoïde, de la largeur et de la longueur du cartilage épiglottique, et du diamètre interne et externe du premier anneau trachéal. Les résultats obtenus fournissent un tableau complet de données déterminant la taille et l'étendue non seulement de ses composants cartilagineux, mais des structures laryngées dans leur ensemble. La connaissance de ces données peut contribuer à préciser la mise en place des électrodes en électromyographie laryngée, à la planification d'une intervention chirurgicale sur les structures laryngées, et à l'analyse du larynx en tomodensitométrie (TDM) et en imagerie par résonance magnétique (IRM).

Key words: Larynx — Anatomy — Morphometry

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The precise knowledge of anatomical structures is a basic pre-condition of any surgical intervention. Thus progress in the field of surgery requires the constant need of revision of human anatomy by new studies, on which new surgical techniques are based. Numerous data on laryngeal dimensions can be found in older textbooks of anatomy. However, there is no information on how these measurements were conducted [6, 12, 17, 20]. Early anatomic investigations of the human larynx from the second half of the 19th century supply information on the comparative dimensions of male and female larynges, but no exact measurements were conducted [7]. Von Luschka, in 1882, described anatomical variations of the larynx and provided morphometric data on the length of the epiglottis, height and width of the cricoid and arytenoid cartilages, and the height of the larynx [14].

Taguchi, in 1889, investigated the topographic anatomy of the larynx, describing its situation relative to the cervical spine and investigating the dimensions of some of the cartilaginous components of the laryngeal skeleton [19]. A first systematic measurement of a human larynx was conducted by Kurz in Shanghai in 1914 on the larynx of a 25 year old Chinese female [10]. In 1927, Waldeyer investigated anthropomorphic details in the larynges of primates and humans [21].

Morphometry of the larynx has since then found only little interest. However, the introduction of computed tomography and magnetic resonance imaging into laryngological imaging and the elaboration of new surgical concepts for the treatment of phonatory disorders has recently awakened new interest in larynx morphometry [4, 8, 9, 13, 18].

The aim of this present study is the exact and extensive description of macro-anatomical dimensions of

laryngeal cartilages, and vocal cords. This study provides reference data of an unselected Central European population for the use in CT and MR imaging and in advanced surgical procedures of the larynx.

Material and methods

The data for this study were obtained from 53 adult autopsy specimens at the Institute of Pathology of the University of Cologne. The larynges were removed on the occasion of routine autopsies 12 to 48 h post mortem. If tumors or traumatic lesions of the larynx became evident during autopsy, the larynges were excluded from this investigation. The larynges were not submitted to fixation, and morphometric measurements were performed immediately after autopsy without any delay. 28 of the deceased were male and 25 were female. The mean age of the 28 men was 60 years (range: 48-95 years), with the mean height being 173 cm (range: 155-189 cm) and the mean body weight 68 kg (range: 46-95 kg). The mean age of the 25 women was 59 years (range: 25-88 years), with the mean height being 161 cm (range: 152-181 cm) and the mean body weight 66 kg (range: 43-110 kg).

During autopsy, the larynx was removed in continuity with the lung, trachea, thyroid gland, and tongue. Prior to any measurements, the larynx had to be freed of these adjacent structures.

The trachea was transected between the seventh and eighth tracheal ring, and the base of tongue in the vallecula glossoepiglottica. The m. constrictor pharyngis and the esophagus were removed as well as the thyroid gland. Ventrally, the m. omohyoideus, m. sternohyoideus and m. sternothyreoides were dissected. The remaining specimen contained the larynx with the attached os hyoideum and the seven most cranial tracheal rings.

Measurements of the undissected specimen and the vocal folds were carried out with a pair of compasses and a vernier calliper prior to the transection of the hyoid bone, the laryngeal cartilages and the tracheal rings. The individual components of the larynx, the hyoid and the trachea were then measured likewise. A complete list of all measurements performed is given in Table 1. Figures 1-15 illustrate most of these measurements.

Results

A total of 95 measurements was performed on each larynx. These included, aside from evaluation of the whole organ, identification of the internal and external diameters of the cricoid cartilage, height and length of the thyroid alae in different levels, angle of thyroid laminae, dimensions of arytenoid cartilages, width and length of epiglottic cartilage, and internal and external diameter of first tracheal rings. The results are reported in detail in Table 2. Mean, minimum, maximum and standard deviation were calculated using Jandel's Sigma Plot software for IBM compatible personal computers. These results are also listed in Table 2.

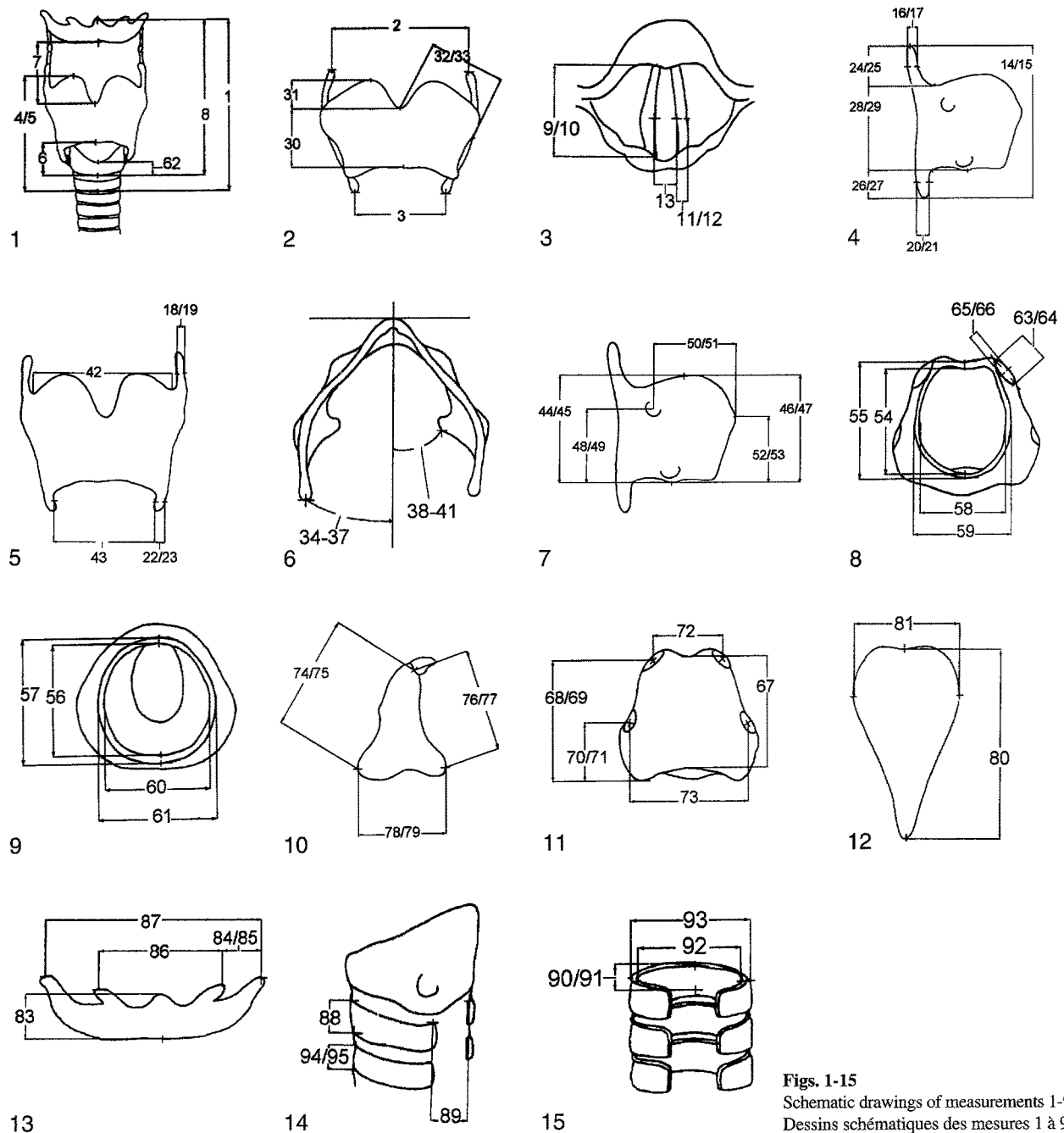
Discussion

Accurate anatomic knowledge is essential in diagnostic and therapeutic procedures in the field of laryngology. Aside from pure anthropometry [1, 2], such information have potential application to studies in laryngeal physiology [16, 23], in advanced methods of larynx imaging [4, 11], and in surgery of the laryngeal framework [8, 9]. A new staging system for the post-surgical classification of larynx carcinoma is based on the metrical extend of the tumor rather than on vague descrip-

Table 1. Morphometric measurements performed on 53 intact human larynges
Mesures morphométriques réalisées sur 53 larynx humains intacts

No.	Figure ^a	Measurement	No.	Figure ^a	Measurement
001	1	Total length of specimen from cranial edge of hyoid to lower edge of first tracheal ring	049	7	Distance between tuberculum thyroideum superius and tuberculum inferius (left side)
002	2	Distance between greater cornua of thyroid	050	7	Distance between tuberculum thyroideum superius and thyroid notch (right side)
003	2	Distance between lesser cornua of thyroid	051	7	Distance between tuberculum thyroideum superius and thyroid notch (left side)
004	1	Distance from cranial edge of thyroid to inferior edge of first tracheal ring (right side)	052	7	Distance between tuberculum thyroideum inferius and thyroid notch (right side)
005	1	Distance from cranial edge of thyroid and inferior edge of first tracheal ring (left side)	053	7	Distance between tuberculum thyroideum inferius and thyroid notch (left side)
006	1	Distance from der lower edge of thyroid to lower edge of cricoid	054	8	Internal sagittal diameter of cricoid (cranial edge)
007	1	Distance from caudal edge of thyroid notch to lower edge of hyoid	055	8	External sagittal diameter of cricoid (cranial edge)
008	1	Distance from lower edge of cricoid to upper edge of hyoid	056	9	Internal sagittal diameter of cricoid (caudal edge)
009	3	Length of right vocal fold	057	9	External sagittal diameter of cricoid (caudal edge)
010	3	Length of left vocal fold	058	8	Internal transverse diameter of cricoid (cranial edge)
011	3	Width of right vocal fold	059	8	External transverse diameter of cricoid (cranial edge)
012	3	Width of left vocal fold	060	9	Internal transverse diameter of cricoid (caudal edge)
013	3	Distance of vocal folds (recorded at proc. vocalis of arytenoids)	061	9	External transverse diameter of cricoid (caudal edge)
014	4	Distance between greater and lesser cornua (right side)	062	1	Height of cricoid arch (ventrally)
015	4	Distance between greater and lesser cornua (left side)	063	8	Length of oval facies articularis arytenoidea (right side)
016	4	Sagittal diameter of greater cornu (right side)	064	8	Length of oval facies articularis arytenoidea (left side)
017	4	Sagittal diameter of greater cornu (left side)	065	8	Width of oval facies articularis arytenoidea (right side)
018	5	Transverse diameter of greater cornua (right side)	066	8	Width of oval facies articularis arytenoidea (left side)
019	5	Transverse diameter of greater cornua (left side)	067	11	Height of cricoid lamina
020	4	Sagittal diameter of lesser cornua (right side)	068	11	Height of cricoid from lower border to facies articularis arytenoidea (right side)
021	4	Sagittal diameter of lesser cornua (left side)	069	11	Height of cricoid between lower rim to facies articularis arytenoidea (left side)
022	5	Transverse diameter of lesser cornua (right side)	070	11	Height of cricoid between lower rim to facies articularis thyroidea (right side)
023	5	Transverse diameter of lesser cornua (left side)	071	11	Height of cricoid between lower rim to facies articularis thyroidea (left side)
024	4	Height of greater cornua (right side)	072	11	Diameter of cricoid between facies articulares arytenoideae
025	4	Height of greater cornua (left side)	073	11	Diameter of cricoid between facies articulares thyroideae
026	4	Height of lesser cornua (right side)	074	10	Distance between processus muscularis and apex of arytenoid cartilage (right side)
027	4	Height of lesser cornua (left side)	075	10	Distance between processus muscularis and apex of arytenoid cartilage (left side)
028	4	Height of thyroid ala between base of greater cornu and base of lesser cornu (right side)	076	10	Distance between processus vocalis and apex of arytenoid cartilage (right side)
029	4	Height of thyroid ala between base of greater cornu and base of lesser cornu (left side)	077	10	Distance between processus vocalis and apex of arytenoid cartilage (left side)
030	2	Distance between thyroid notch and incisura thyroidea inferior	078	10	Distance between processus muscularis and vocalis of arytenoid cartilage (right side)
031	2	Height of thyroid notch	079	10	Distance between processus muscularis and vocalis of arytenoid cartilage (left side)
032	2	Width of thyroid ala (right side)	080	12	Length of epiglottis
033	2	Width der thyroid ala (left side)	081	12	Width of epiglottis
034	6	Internal angle of thyroid ala between thyroid notch and base of greater cornua (right side)	082	no fig.	Thickness of epiglottis
035	6	Internal angle of thyroid alae between thyroid notch and base of greater cornua (left side)	083	13	Height of hyoid in the midline
036	6	Internal angle of thyroid alae between thyroid notch and tip of greater cornua (right side)	084	13	Distance between greater and lesser cornua of hyoid bone (right side)
037	6	Internal angle of thyroid alae between thyroid notch and tip of greater cornua (left side)	085	13	Distance between greater and lesser cornua of hyoid bone (left side)
038	6	Internal angle of thyroid alae between incisura thyroidea inferior and base of lesser cornua (right side)	086	13	Distance between lesser cornua of hyoid bone
039	6	Internal angle of thyroid alae between incisura thyroidea inferior and base of lesser cornua (left side)	087	13	Distance between greater cornua of hyoid bone
040	6	Internal angle of thyroid alae between incisura thyroidea inferior and tip of lesser cornua (right side)	088	14	Height of first tracheal ring
041	6	Internal angle of thyroid alae between incisura thyroidea inferior and tip of lesser cornua (left side)	089	14	Width of paries membranaceus of first tracheal ring
042	5	Distance between bases of greater cornua of thyroid	090	15	Sagittal diameter of first tracheal ring (inner diameter)
043	5	Distance between bases of lesser cornua of thyroid	091	15	Sagittal diameter of first tracheal ring (outer diameter)
044	7	Height of thyroid ala from cranial rim to tuberculum inferius (right side)	092	15	Transverse diameter of first tracheal ring (inner diameter)
045	7	Height of thyroid ala from cranial rim to tuberculum inferius (left side)	093	15	Transverse diameter of first tracheal ring (outer diameter)
046	7	Height of thyroid ala between cranial and caudal rims (right side)	094	14	Height of second tracheal ring
047	7	Height of thyroid ala between cranial and caudal rims (left side)	095	14	Height of third tracheal ring
048	7	Distance between tuberculum thyroideum superius and tuberculum inferius (right side)			

^aThese figures denominate the corresponding illustration in Figs. 1-15; *no fig.* = no corresponding illustration of measurement^aCes figures dénomment les illustrations correspondantes sur les figs. 1 à 15 ; *no fig.* = no correspondant aux mesures sur les illustrations



Figs. 1-15

Schematic drawings of measurements 1-95
 Dessins schématiques des mesures 1 à 95

tions of its visible spread [5]. It is obvious that the application of such an elaborate system requires a profound knowledge of the normal morphometry of the larynx. Besides, there is a certain general interest in knowledge of measurements of the human body for its own sake.

In spite of all the differences in material, method and number of investigated specimens some data of this study are quite similar to the few measurements reported earlier [1, 3, 11, 22]. This is especially true for the observed sex dimorphism of the larynx, characterised by an about 10-

20° greater angle formed by the laminae thyroidea in females and about a 5 mm longer glottis in male larynges. Due to the irregular shape of the larynx, definitions of measured values may vary from one study to another. A comparison with those data of laryngeal morphometry found

Table 2. Results of morphometric measurements on 53 intact human larynges (Distances are given in mm, angles are given in degrees)
 Résultats des mesures morphométriques sur 53 larynx humains intacts (Distances données en mm, angles donnés en degrés)

Measure- ment	Males					Females				
	n	Mean	Mini- mum	Maxi- mum	SD	n	Mean	Mini- mum	Maxi- mum	SD
1	28	71.3	52	80	6.06	25	60	48	70	4.62
2	28	38.2	27	63	7.67	25	36.9	26	48	6.41
3	28	35.9	26	43	3.84	25	29.9	24	36	3.54
4	28	53.3	41	63	4.59	25	45.3	38	52	3.60
5	28	53.3	41	63	4.59	25	45.4	38	51	3.37
6	28	16.1	12	19	2.30	25	14.3	10	18	2.15
7	28	18.7	11	30	3.53	25	13.1	8	18	2.32
8	28	63.1	47	71	4.86	25	51.2	41	58	3.48
9	19	13.8	11	18	2.92	23	10.7	6	13	1.63
10	19	13.8	11	18	2.92	23	10.7	6	13	1.63
11	5	4.2	3	6	1.02	7	3.1	2	5	1.07
12	5	4.2	3	6	1.02	7	3.1	2	5	1.07
13	19	6.2	5	8	1.79	23	4.9	4	7	1.27
14	28	43.9	35	52	4.63	25	36	28	43	3.84
15	28	45.1	36	54	4.18	25	36.5	29	44	3.94
16	28	3.2	3	4	0.41	25	2.8	2	3	0.43
17	28	3.1	2	4	0.37	25	2.6	2	3	0.48
18	28	3.8	3	5	0.78	25	3.2	2	4	0.61
19	28	3.8	2	5	0.49	25	3.3	2	4	0.60
20	28	4.1	3	6	0.70	25	3.7	3	5	0.46
21	28	3.9	3	5	0.67	25	3.7	3	5	0.60
22	28	5.4	3	10	1.29	25	4.2	2	6	0.83
23	28	5.1	3	7	0.83	25	4	2	5	0.69
24	28	14.9	8	20	2.94	25	13.1	8	19	2.35
25	28	14.5	10	20	3.04	25	13.4	9	19	2.59
26	28	8.3	6	11	1.27	25	7.4	5	11	1.24
27	28	8.9	7	12	1.13	25	7.8	6	10	1.22
28	28	23.9	17	28	2.49	25	18.6	15	22	1.83
29	28	24.7	17	28	2.48	25	18.7	14	22	1.95
30	28	18.5	10	22	2.54	25	15.8	13	17	1.07
31	28	9.0	5	12	1.82	25	6.4	4	9	1.33
32	28	41.9	30	47	3.38	25	31.2	22	35	2.73
33	28	41.5	29	47	3.70	25	31.2	23	35	2.83
34	28	34.1	30	47	4.82	25	41.5	32	50	4.71
35	28	31.6	29	47	6.29	25	39.2	27	50	5.42
36	28	27.6	18	50	6.11	25	33.1	27	40	4.06
37	28	25.6	15	50	7.38	25	32.1	23	45	5.37
38	28	42.6	32	55	4.67	25	44.8	35	55	3.93
39	28	43.4	30	55	4.65	25	44.6	30	53	5.06
40	28	36.3	24	45	5.89	25	35.6	23	45	5.88
41	28	37.3	30	45	5.48	25	37.6	30	45	4.87
42	28	42.6	24	53	6.08	25	37	18	45	5.38
43	28	33.9	26	40	3.17	25	27.1	20	32	2.71
44	28	28.6	21	34	2.37	25	21.8	18	26	1.94
45	28	29.2	22	36	2.74	25	22	17	26	2.30
46	28	27.4	20	34	2.47	25	22.2	19	31	2.85
47	28	27.6	21	33	2.32	25	22.1	18	30	2.67
48	28	23.7	19	30	2.94	25	18	14	24	2.33
49	28	24.3	18	30	3.08	25	17.9	13	23	2.47

(Table 2. continued next page)

in the literature is of only limited use. The fact that some of the absolute data differ quite heavily between the studies may be explained by different definitions of measuring points. Therefore, an effort was made in this study to define exactly

every single measurement (Table 1 and Figs. 1-15). Another explanation may be the eventual ethnical differences between the studied populations. The few studies which could be reasonably compared with, were performed on specimen of Nigerian

[2], Italian [3], German [11], and North American [15] populations, respectively. General differences to the larynges from the population in these studies cannot be ruled out.

Due to the elasticity of the vocal cords exact measurement was extremely difficult after dissection of the larynx, as our own attempts in this study have shown: the length of the vocal cords could be determined in only 19 of 28 males and in 23 of 25 females. The reliability of these measurements must therefore be questioned. The width of the vocal cords could be determined in 5 of 28 males and in 7 of 25 females. Quality of these measurements must be considered to be even worse. We conclude from these observations that the technique applied is not suitable for the accurate description of vocal cord morphometry. However, the same should be true for data reported earlier, as they were collected in a similar way [1, 2, 11, 15]. Investigations of whole-organ serial sections could fill this gap [4].

The results obtained provide a full scale of data determining the size and extend not only of its cartilaginous components, but of the laryngeal framework as a whole. Compared to measurements performed on dissected parts of the laryngeal skeleton [11], the present data can be considered to be more reliable, because the structures of interest remain in their undisturbed anatomical context. The knowledge of these data may contribute to a precise positioning of electrodes in laryngeal electromyography, to the planning of laryngeal framework surgery, and to the analysis of CT- and MRI-scans of the larynx.

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Table 2. Results of morphometric measurements on 53 intact human larynges (continued)
Résultats des mesures morphométriques sur 53 larynx humains intacts (suite)

Measure- ment	Males					Females				
	n	Mean	Mini- mum	Maxi- mum	SD	n	Mean	Mini- mum	Maxi- mum	SD
50	28	35.0	27	42	3.65	25	26.9	20	31	2.45
51	28	34.9	25	41	3.46	25	26.8	20	32	2.70
52	28	29.8	21	39	3.27	25	23.4	20	30	2.57
53	28	29.5	21	36	2.97	25	23.4	20	26	2.15
54	28	21.6	16	34	3.61	25	17.4	13	21	1.92
55	28	30.9	24	37	3.06	25	25.2	21	30	2.33
56	28	20.1	14	24	2.30	25	16.4	13	21	1.90
57	28	27.1	19	34	3.13	25	23.2	20	28	1.83
58	28	15.3	11	19	1.88	25	12	9	14	1.23
59	28	26.4	21	30	2.40	25	21.4	16	26	2.04
60	28	18.2	13	24	2.18	25	14.5	10	17	1.63
61	28	27.6	23	32	2.33	25	22.8	19	27	2.01
62	28	6.9	5	10	1.35	25	6.2	4	9	1.11
63	28	8.8	6	11	1.19	25	7.2	5	9	1.02
64	28	8.6	7	12	1.07	25	7.2	5	9	1.08
65	28	5.2	3	7	0.70	25	4.4	3	6	0.69
66	28	4.7	3	6	0.74	25	4.7	3	6	0.73
67	28	24.6	21	28	1.84	25	21.3	19	24	1.44
68	28	22.3	19	25	1.63	25	19.8	18	22	1.20
69	28	23.1	18	26	1.58	25	20.2	18	22	1.07
70	28	10.2	8	14	1.92	25	9.4	7	13	1.50
71	28	10.8	8	15	1.98	25	9.9	7	16	1.80
72	28	19.9	11	32	3.97	25	16.2	13	20	1.70
73	28	29	20	34	3.13	25	24.4	20	28	2.45
74	24	17.1	12	24	2.44	21	14	8	18	2.24
75	23	16.8	12	22	2.75	21	13.9	8	20	2.70
76	24	17.0	14	33	3.67	21	12.7	9	15	1.78
77	23	16.2	11	24	2.57	21	12.4	8	18	2.28
78	24	13.5	8	18	1.89	21	11.7	9	14	1.36
79	23	13.3	10	16	1.45	21	13.3	10	20	2.75
80	28	34.6	28	46	3.61	25	28.2	22	33	2.62
81	28	25.2	19	36	3.20	25	19.9	15	24	2.35
82	28	3.5	2	5	0.87	25	2.9	2	5	0.77
83	28	11.4	9	13	1.01	25	10.1	8	16	1.57
84	20	27.5	16	36	5.03	22	24.5	13	31	4.61
85	28	28.3	16	38	4.60	22	24.2	13	31	4.64
86	28	31.9	23	44	5.68	23	27.9	22	40	4.02
87	28	44.4	26	66	8.41	24	40.1	24	50	7.26
88	28	7.9	3	12	2.24	25	8.6	4	13	2.19
89	28	18.9	12	30	4.26	25	14.3	7	23	3.53
90	28	17.6	14	21	1.61	25	14	10	17	1.93
91	28	22.6	19	26	1.70	25	18	13	22	1.91
92	28	18.7	12	24	2.65	25	15.3	9	19	2.13
93	28	24.1	10	28	2.09	25	19.6	11	23	2.74
94	28	5.6	3	10	1.42	24	4.7	3	6	0.68
95	26	4.9	4	6	0.66	24	4.3	3	5	0.52

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