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A Study on Anatomical Variations of Hyoid-thyroid Complexes of Adult Post-mortem Specimens from Sri Lanka

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Abstract

Studies done on anatomical variations of laryngeal skeleton are limited throughout the world. Some are based on numerically constricted sample-sizes. This is the pioneer research conducted in Sri Lanka. An awareness of the anatomical variations of this important area is crucial for the accurate interpretation of postmortem findings specially when pressure on the neck is suspected. The study was conducted to identify the common anatomical variations of the hyoid-thyroid complexes, their correlation with the age and sex, using 241 adult postmortem laryngeal skeletons. Ethical clearance was obtained from the ethics review committee of the Colombo South Teaching Hospital. After obtaining the written informed consent from the legal claiments of the body. Hyoid and larynx were removed during routine autopsy, examined afresh after manual de-fleshing, preserved in formalin and carefully dissected and subjected to X-ray. Findings were manually tabulated for each case. Some crucial findings significantly diverge from comparative studies done elsewhere. Fusion of the greater horn of hyoid was very variable with no significant co-relation with the advancement of age. In 13% of cases lesser horns were totally absent. In 80% of cases, lesser horns were symmetrical. In a minority of cases lesser horns were unusual in anatomy. Significant variations of mobility of lesser horns, presence or absence of projections on the body of the hyoid, shape of the hyoid, angle between the thyroid laminae, presence of triticeous cartilages, their site and number, shortening of superior cornua of thyroid, direction, length and angulation of the superior cornua, angle between thyroid laminae etc. had been found. The presence of triticeous cartilages in 63% of cases in Sri Lanka is a notable finding which is prone to be mistaken for a thyroid superior cornual fracture.

Keywords: laryngeal skeleton, triticeous cartilages, superior cornua (of thyroid), greater and lesser horns (of hyoid)

Introduction

Evolution has given certain animals the special ability of generating sounds. Vocalization is maximum among humans compared to all other animals including birds and primates. The soundbox of the human body is the larynx which is located in the anterior compartment of the neck, suspended from the hyoid bone spanning between third to sixth cervical vertebrae. It is continuous inferiorly with the trachea and opens superiorly into the laryngeal part of the

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pharynx. The larynx is formed by a cartilaginous skeleton which is held together by ligaments, membranes and muscles. [1] The normal adult hyoid-larynx complex is described as combination of hyoid apparatus (i.e. styloid processes, stylohyoid ligaments and lesser horns of the hyoid), body and greater horns of the hyoid bone, thyroid, cricoid and arytenoid cartilages and their ligaments proper. The thyroid cartilage encompasses its superior and inferior cornua. Normal length of the styloid process is generally described as 20–30 mm, though attention had not been paid to the anatomy of the styloid process in our study. [2] Larynx consists of only one bone which is the hyoid. It is a 'U' shaped structure located in the anterior neck. It lies at the base of the mandible (approximately at the level of C3), where it acts as a site of attachment for the anterior neck muscles. The hyoid bone is unique in the fact that it does not articulate with any other bone as it is suspended in place by the muscles and ligaments attached to it. As far as the structure is concerned, the hyoid is composed of a body, two greater and two lesser horns. The body is the central part of the hyoid bone. It has an anterior convex surface and a concave posterior surface. Greater horn projects from each end of the body in a posterior, superior and lateral direction. It acts as a site of attachment for numerous neck muscles. Lesser horn arises from the superior aspect of the hyoid bone near the origin of the greater horn and it projects supero-posteriorly (towards the styloid process of the temporal bone). The stylohyoid ligament is attached to the apex of the lesser horn. [3]

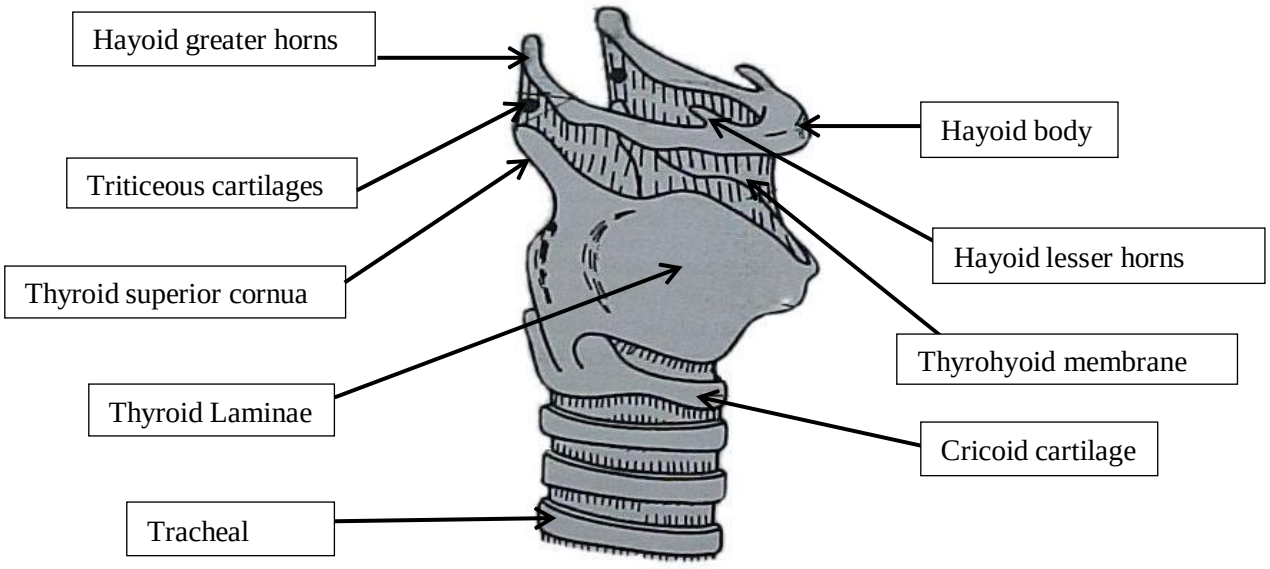

Figure 1: anatomy of the larynx

The thyroid cartilage part of which forms the Adam's apple, is the largest and the uppermost of the nine cartilages comprising the larynx or the voice box. It houses the vocal folds better known as the vocal cords. The thyroid cartilage is composed of two plates termed thyroid laminae that join in the front midline at an angle of 90 to 120 degrees. The visible protrusion it creates on the

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front of the neck is generally more prominent in men because of the sharper angle. The thyroid cartilage typically grows larger during the teenage years especially in boys and is considered as a secondary sexual characteristic in males which goes hand in hand with deepening of their voice. Thyroid cartilage plays a significant role in the production of the human voice providing protection and support for the vocal folds. The muscles of the larynx act on the skeletal structures including the thyroid cartilage to enhance the vibration of the vocal folds which is necessary for precise vocalization. [4]

Anatomical variations of the hyoid-larynx complex occur in 4–30% of the general population. Anomalies and variations of this complex are of great clinical importance for radiological examination and interpretation as well as in operative surgery of the neck region. Very few comprehensive studies had been conducted in the western world on this topic. This is the pioneer research done in Sri Lanka. Practical difficulties encounterd in collecting an adequate sample may be the reason for scarcity of research on this important area. An understanding and an awareness of the anomalies and anatomical variations of this region is equally significant for the forensic pathologist who conducts an autopsy and attempts to interpret naked eye findings of a death with suspected fatal pressure or penetrating injuries over neck area such as manual strangulation, ligature strangulation, hanging, firearm injuries and stabs. [2]

Anomalies of the hyoid bone involving differential development of the greater and lesser horns could result in the asymmetrical development of greater horn or agenesis of the lesser horn. [5] Atypical morphological variations including differences in the shape of the hyoid bone, osseous extensions possibly resulting from Eagle Syndrome (ossification of the stylohyoid ligament) or from unknown etiology have also been reported.

Figure 2: human hyoid bone

Minor variations in hyoid-larynx comples consist of age-related fusion of the body with the greater and/or lesser horns by ankyloses of the joints etc. [6] [7] Several anomalies and anatomical variations are in record with relation to the thyroid cartilage as well. Thyroid cartilage calcification, cystic changes in the thyroid cartilage, agenesis of the thyroid cornuae, presence of triticeaous cartilages, ectopic superior thyroid cornuae, terminal segmentation of the thyroid cornuae and buckled thyroid cartilage are some of them. [8] [2]

Morphological variations of the hyoid bone are closely related to the gender, race, body proportions/built and the age. [9] European hyoids are broader and shorter than African ones. Studies have found that the distal ends of the greater horns are significantly longer in women than in men. Male hyoids are generally larger than female ones. [7] Inward curving and fattening

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of the greater horns are typical for male hyoids. Male hyoids are more susceptible to age-related modifications. Males show a higher degree of thyroid ossification ultimately leading to the completely ossified os thyroideum which is more prone to fractures of the superior cornua due to the absence of elasticity. Finally, muscle attachment sites also show some individual variations. Certain minor variations occur so often that they cannot be considered as anatomical variations. [(2)]The synchondrosis between the greater horn and the body of the hyoid presents as a vertical radiolucent line in neck radiographs which may be mistaken for a fracture. Since it is a normal feature in many hyoid bones, especially in the younger age groups, it is important to identify and recognize this condition as a normal variant. [(10)] The presence of triticeous cartilages at the end of the superior cornua of the thyroid may also be mistaken for a fracture by the novice pathologist.

Objectives

The objectives of the research was to find out the anatomical variations of the hyoid larynx complexes in Sri Lankan population and compare the findings with the research done elsewhere.

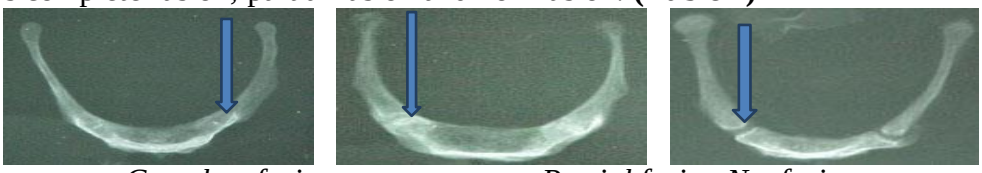
Methodology

The study had been conducted based at the Office of the Judicial Medical Officer, Colombo South Teaching Hospital, Kalubowila, Sri Lanka. Data collection was done over a nine-month period. Two hundred and forty-one (n=241) adult hyoid larynx complexes were collected during routine autopsy after obtaining written informed consent from the legal claiment of the dead body. Children below 18 years of age, those who died due to perforating and sharp trauma to neck region and cases where consent had not been given by the relatives were excluded. Both males and females were included. Collection and analysis of results was done at three stages. The specimen was examined afresh after dissection from the neck. Then they were defleshed, preserved for two weeks in 10% formol saline, de-fleshed again and examined. The clean skeletal samples were subject to X-ray and X-rays examined by the researchers as well as by the consultant radiologist of Kalubowila hospital. The results were recorded manually at each of the three stages and compared. Final results were obtained after carefully considering the results at each level specially in the rare event where there happens to be a slight discrepancy among the findings at each of the three stages. Analysis was done using SPSS 25.

Results

The following variations were identified in relation to the hyoid bone.

- The degree of fusion of the greater horn with the body of the hyoid bone could be of three types as complete fusion, partial fusion and non-fusion. **(Table 1)**



Complete fusion *Partial fusion* *Nonfusion*

Figure 3: The degree of fusion of the greater horn with the body of the hyoid bone

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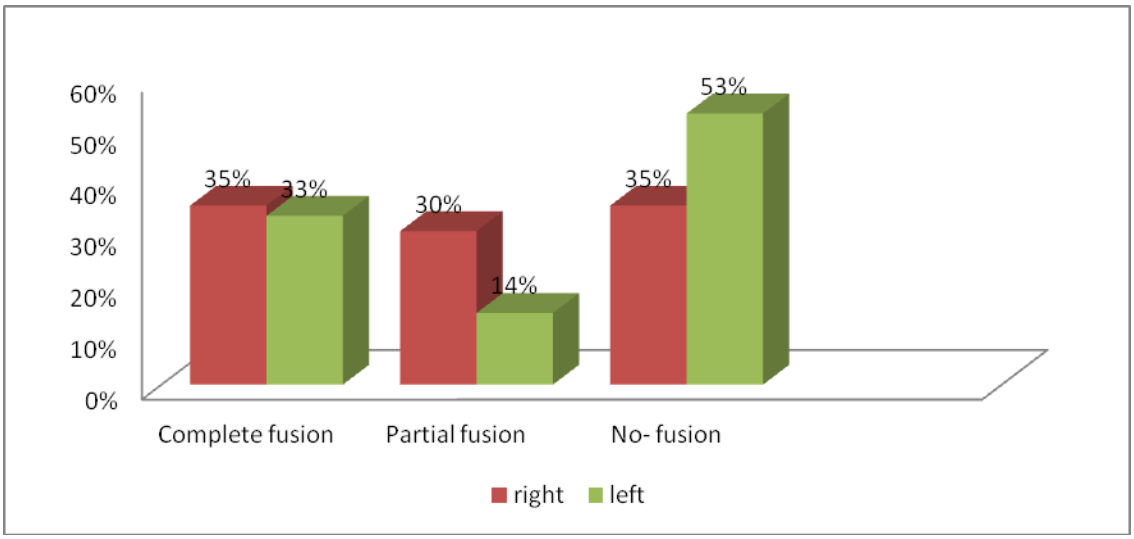
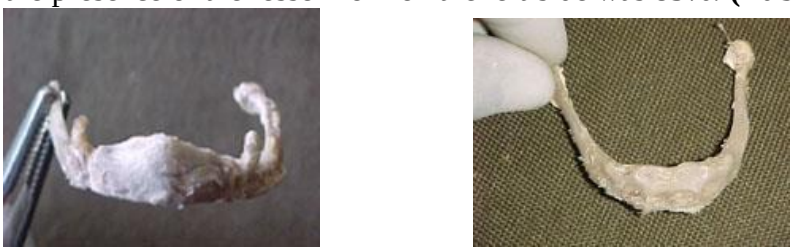
Degree of fusion	Left %	Right %
Complete fusion	33	35
Partial fusion	14	30
Non-fusion	53	35

Table 1: ***The degree of fusion of the greater horn with the body of the hyoid***



- In this study several variations were identified in relation to the lesser horn. Some specimens did not contain a lesser horn on one side. Only 89% had lesser horn on the right side and the presence of the lesser horn on the left side was 85%. **(Table 2)**



Lesser horn present *Lesser horn absent*

Figure 4: Presence or absence of lesser horn

Presence or absence of lesser horn	Left %	Right %
Present	85.3	89.3
Absent	14.7	10.7

Table 2: ***The presence or absence of lesser horn***

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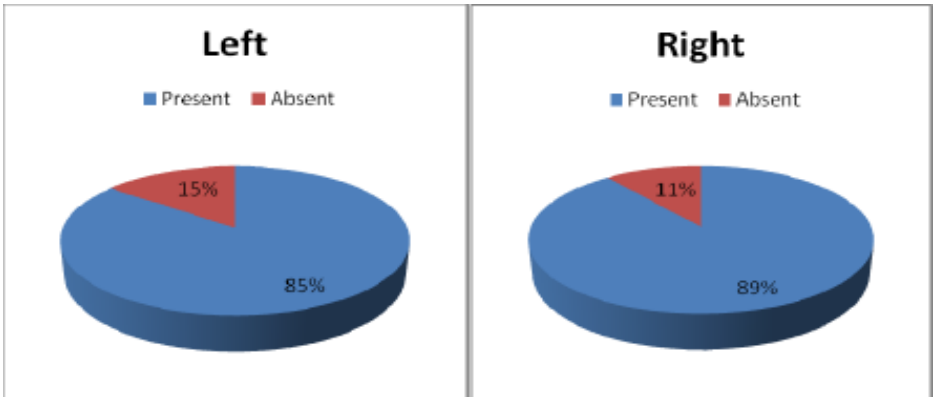


- There were variations in the site of attachment of the lesser horn. Some were attached to the body of the hyoid while the others were attached to the greater horn. **(Table 3)**

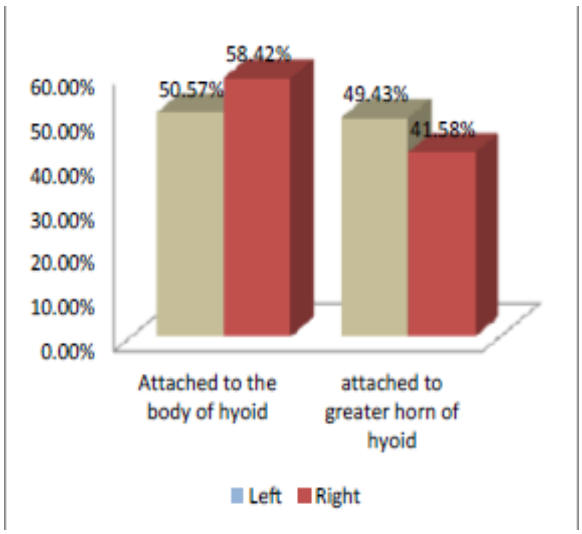
Attached to the body of the hyoid

Attached to the greater horn of hyoid

Figure 5: Site of lesser horn attachment

Site of attachment (lesser horn)	Left%	Right %
Body of hyoid	50.57	58.42
Greater horn of hyoid	49.43	41.58

Table 3: ***The site of attachment of lesser horn***



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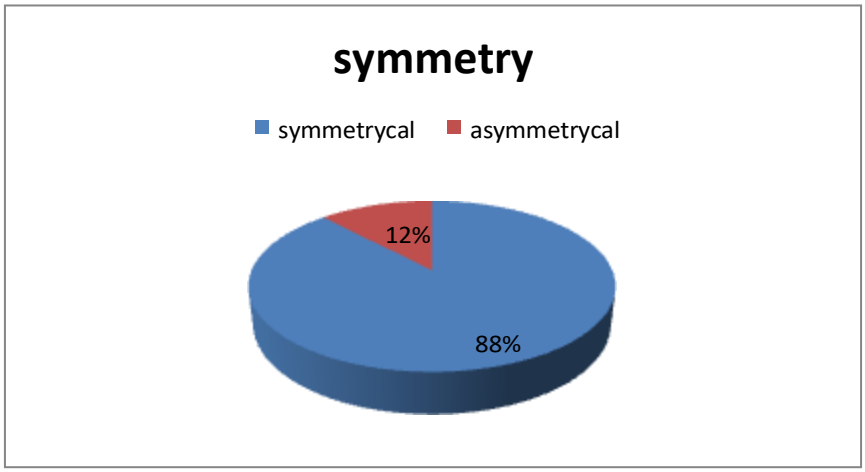
- The symmetry of the lesser horns on either side was analyzed (out of the percentage of hyoid bones where both lesser horns were present). Out of such specimens 78.% were symmetrical and only 12% were found to be asymmetrical.

Symmetrical

Asymmetrical

Figure 6: Symmetry of the lesser horns



- In this research, variations in the mobility of the lesser horns were studied. (as a percentage of all hyoid bones collected for the study and not as a percentage of hyoid bones where both lesser horns were present). 66.67% of left sided lesser horns were mobile whereas on the right side it was 58.82%. Out of all specimens 18.63% of the left sided lesser horns were immobile and on the right side the percentage of immobility was 28.43%. **(Table 4)**

Mobility of lesser horns	Left%	Right %
Mobile	66.67	58.82
Immobile	18.63	28.43

Table 4: ***The mobility of the lesser horn***

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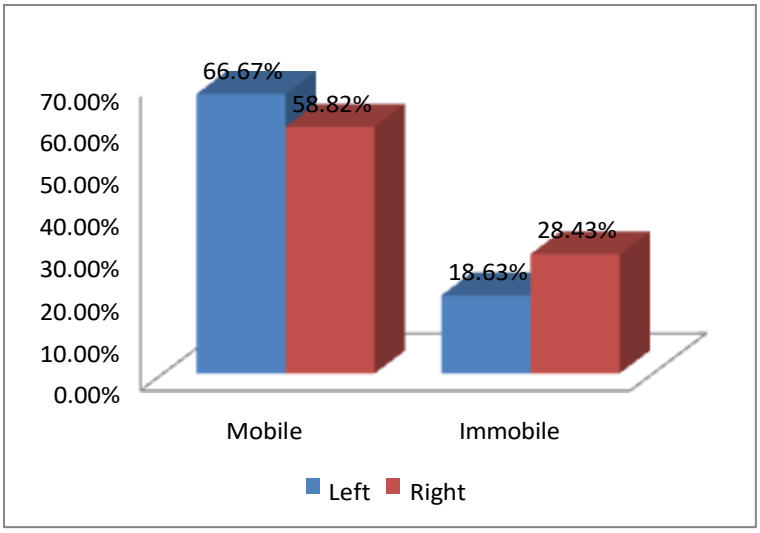
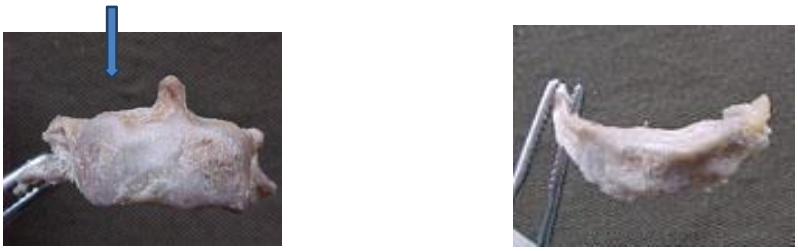
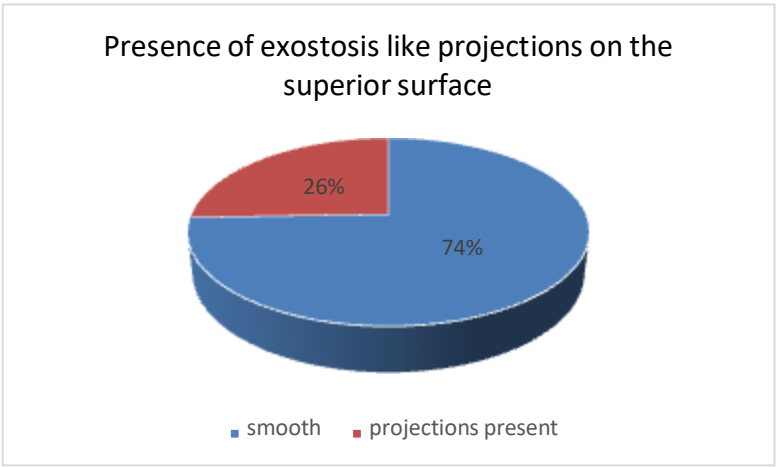


- The presence of 'exostosis-like projections' on the superior surface of the body of the hyoid bone was studied. Only 25.50% of all specimens had this variation. All the other specimens (74.5%) had a smooth superior surface of the hyoid.



exostosis-like projections' present *smooth superior surface (no projections)*

Figure 7: presence or absence of exostosis on superior surface



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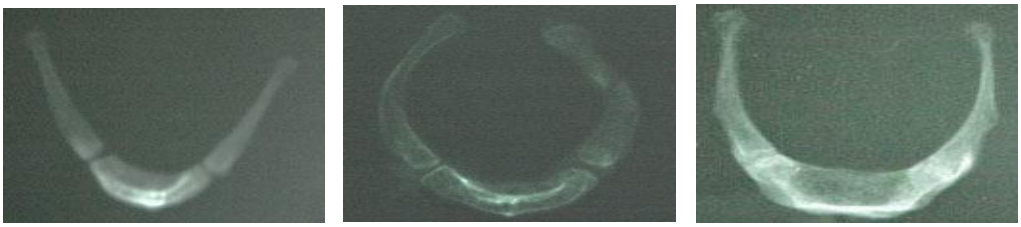
- The shape of the hyoid bone is mainly determined by the relative angulation of the two greater horns. Three variations could be found based on the direction of the greater horn as diverging, converging and parallel. (Table 5)

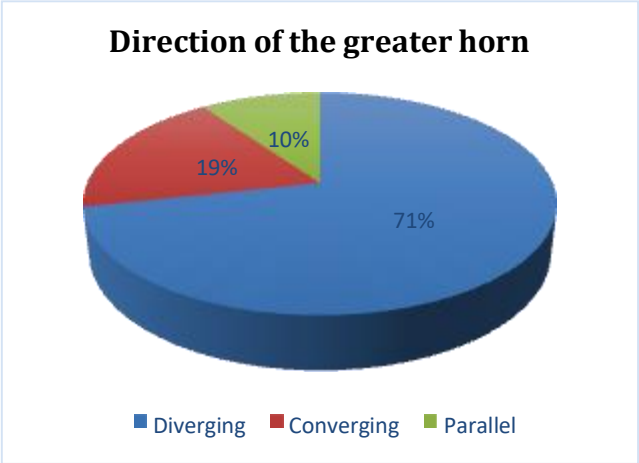


Diverging *Converging* *Parallel*

Figure 8: Variations in the direction of the greater horn/shape of the hyoid

Shape of the hyoid	% of the variation
Diverging	71
Converging	18.62
Parallel	9.81

Table 5: ***Variations in the direction of the greater horn/shape of the hyoid***



The following variations were identified in relation to the thyroid cartilage

- The angle of the thyroid cartilage is formed by the midline fusion of the two thyroid laminae. This angle could be acute or obtuse. 24.51% of the specimens had an acute angle which is less than 90 degrees and 75.49% had a wide angle which is more than 90 degrees.

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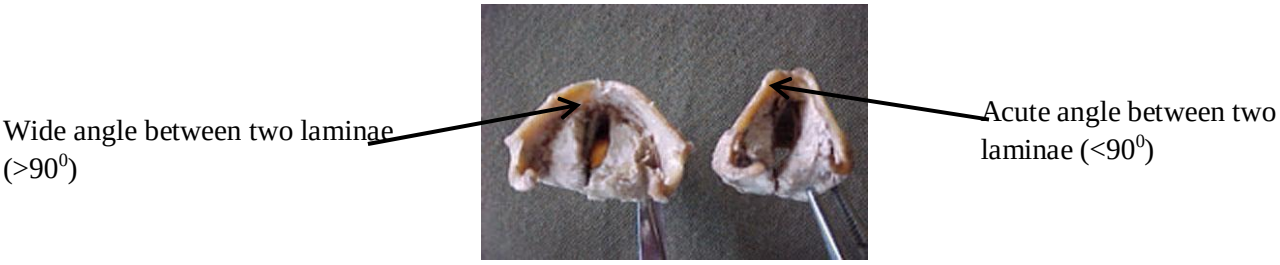
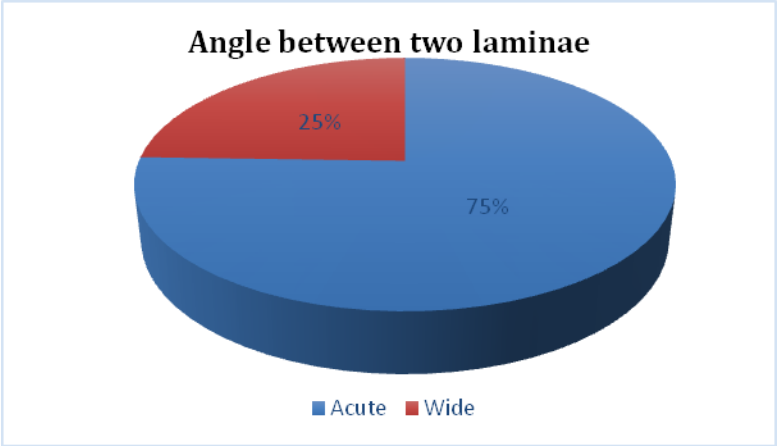


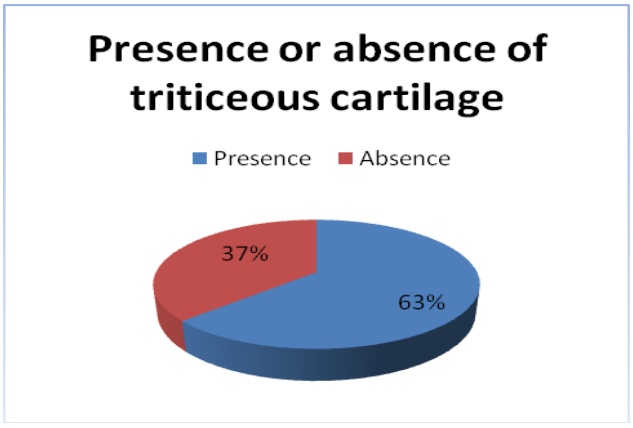
Figure 09: Variations in angle between two laminae



- Triticeous cartilages are usually bilateral ovoid structures found as a non-essential component of the laryngeal skeleton located centrally in the lateral thyrohyoid ligament at the level of third and fourth cervical vertebrae (C3-C4). [(11)]. Out of all specimens, 63% had triticeous cartilages and 37% did not. (**Table 6)**

Triticeous cartilages	% of the variation
Present	63
Absent	37

Table 6: ***Triticeous cartilages***



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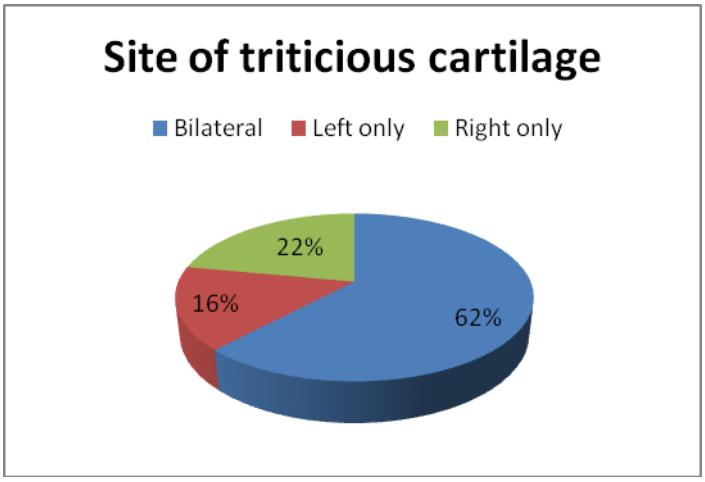
- Among the specimens which contained triticeous cartilages, 62% had them bilaterally, 16% on the left side alone and 22% on the right side only. (**Table 7)**

Side of the attachment	% of the variation
bilaterally	62
Right side only	22
Left side only	16

Table 7: ***Site of Triticeous cartilages attached***



- In this study we also noticed certain variations in the superior cornu of the thyroid cartilage. Out of them; some specimens did not have a superior cornu of the thyroid on both sides. Some contained a shortened superior cornu while in some specimens there was no change in the length of the superior cornua. **(Table 8)**

Absence of the superior cornua *Shortened superior cornua* *No change in the length of superior cornua*

Figure 10: Type of the variation of the superior cornua

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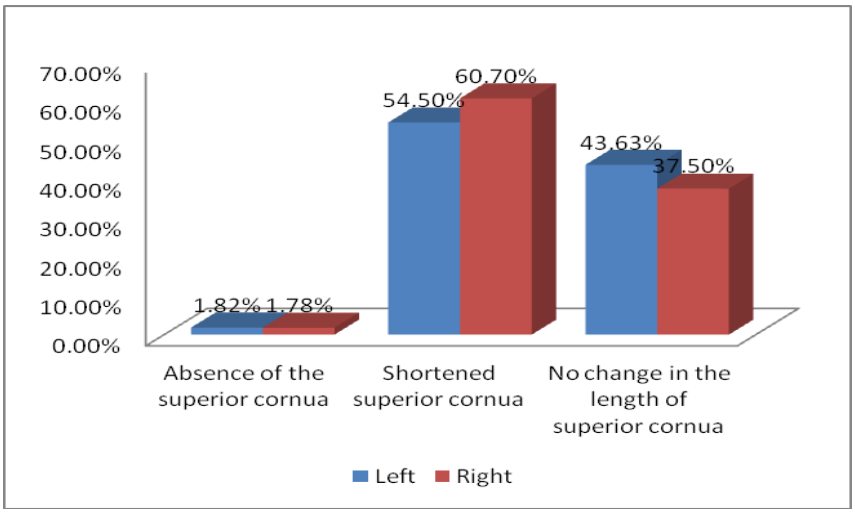
Type of the variation of the superior cornua	% variation on left side	% variation on right side
Absence of the superior cornua	1.82	1.78
Shortened superior cornua	54.5	60.70
No change in the length of superior cornua	43.63	37.5

Table 8: ***Variations of the superior cornua in the presence of triticeous cartilagesn***



- Anterior posterior direction (orientation) of the superior cornua in relation to thyroid laminae also showed some variations such as bending forward, being straight and bending backward. (Table 9)

Bent forward *Straight* *Bent backward*

Figure 11: Direction of the superior cornua

Direction of the superior cornua	% variation on left side	% variation on right side
Bent forward	7.8	5.9
Straight	21.6	20.6
Bent backward	69.6	71.6

Table 9: ***Variations of the direction of the superior horn***

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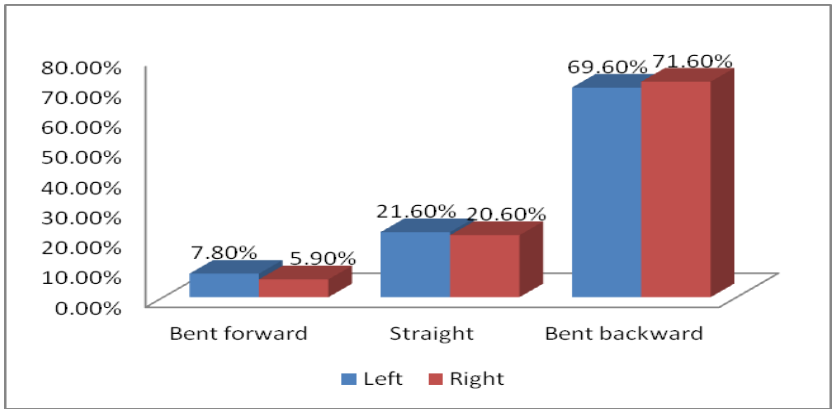
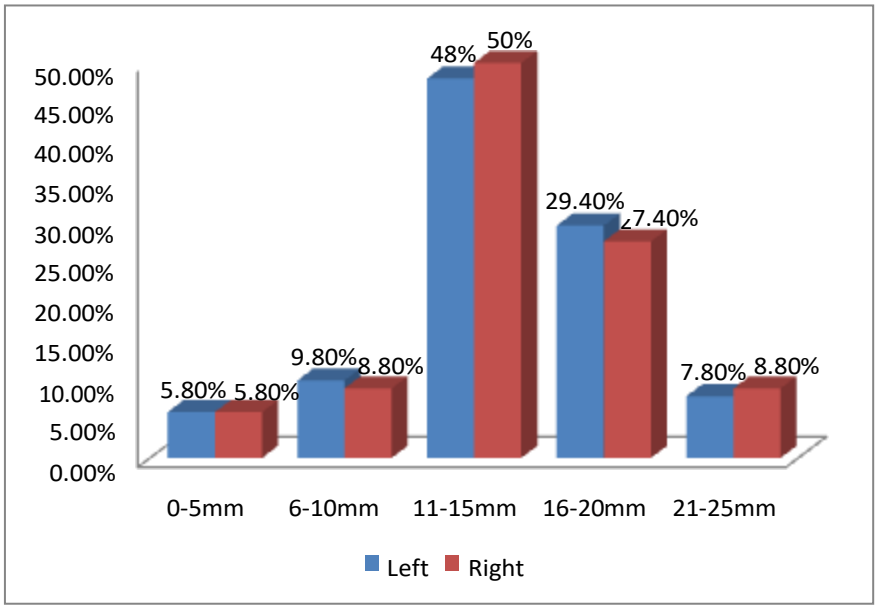


- There were significant variations in the length of the superior cornua. The measurements are taken in mili meteres. (Table 10).

Length (mm)	Left %	Right %
0-5	5.8	5.8
6-10	9.8	8.8
11-15	48	50
16-20	29.4	27.4
21-25	7.8	8.8

Table 10: ***Length of the superior cornua***



- The correlation of these variations with related to the age and the sex are also analyzed in this study. The table below shows the variations in the fusion of greater horns of the hyoid in relation to the advancement of age. This shows that there is no relationship

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between the degree of fusion of the greats horns with the body of the hyoid and the advancement of age. (Table 11)

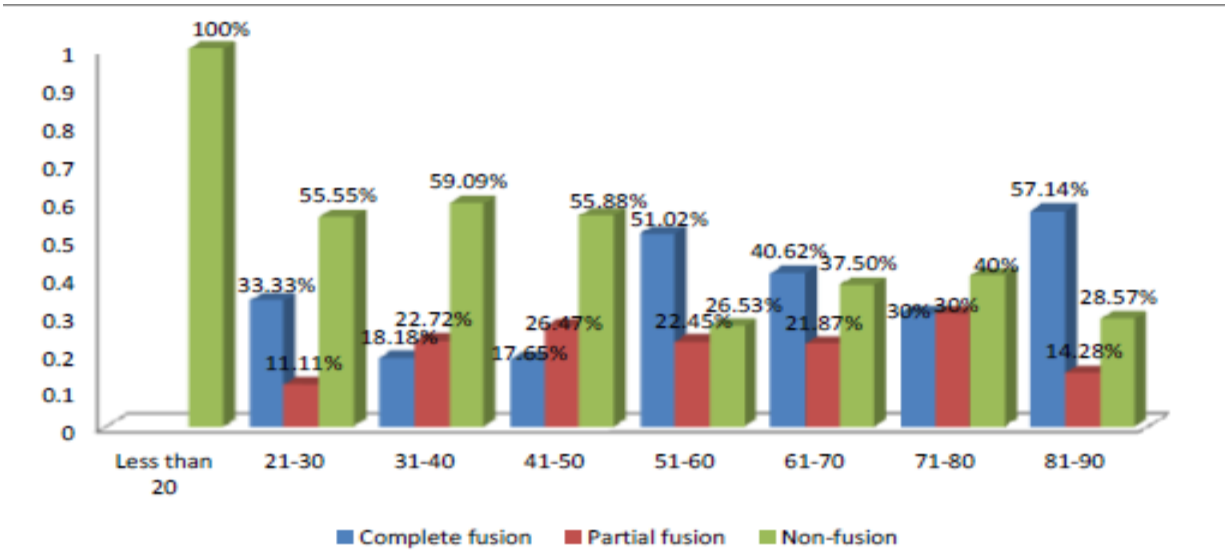
	Age group (years)	Complete fusion	Partial fusion	Non-fusion
1.	Less than 20			100%
2.	21-30	33.33%	11.11%	55.55%
3.	31-40	18.18%	22.72%	59.09%
4.	41-50	17.65%	26.47%	55.88%
5.	51-60	51.02%	22.45%	26.53%
6.	61-70	40.62%	21.87%	37.5%
7.	71-80	30%	30%	40%
8.	81-90	57.14%	14.28%	28.57%

Table 11: ***Variations in the fusion of the greater horns with advancement of age.***

- When considering the correlation of the angle between the two thyroid laminae with the gender, it was evident that, 80.5% of males had an acute angle and the remaining 19.5% of the males had wide angles. In females, only 60% had acute angles and the remaining 40% had wide angles. This is one reason why thyroid cartilage becomes prominent during puberty in males. (Table 12)

Gender	Wide angle	Acute angle
Male	19.5%	80.5%
Female	40%	60%

Table 12: ***Angle between two laminae of the thyroid cartilage in males and females***



- The presence of triticeous cartilages was commoner among males than among females. (Table 13)

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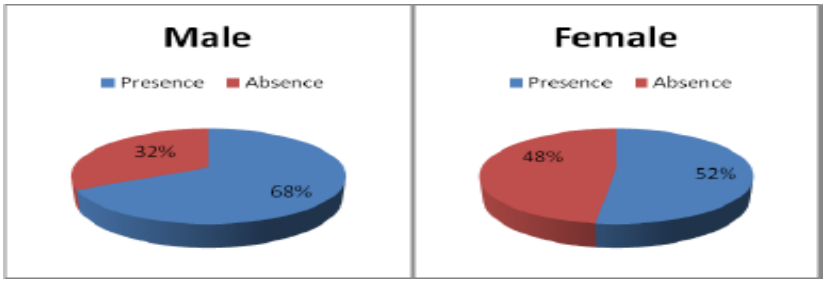
Triticeous cartilages and gender	Presence	Absence
Male	67.53%	32.47%
Female	52%	48%

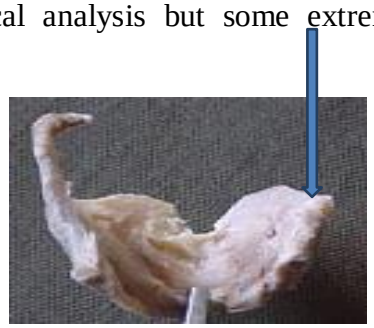
Table 13. ***Tritieceous cartilages and gender***



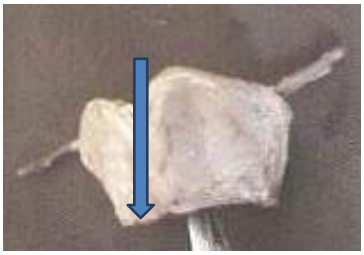
Some other variations found in this study were bilateral elongation of lesser horns, unilateral elongation of lesser horn, unilateral absence of superior cornua, superior cornua connected to the thyroid laminae with a fibrous band (non-fusion) and hyoid bone fused with thyroid superior cornua etc. These were numerically insignificant for statistical analysis but some extreme examples are elaborated with photographs below.

Bilateral elongation of lesser horns

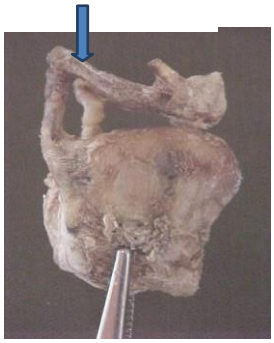
Unilateral elongation of lesser horn



Unilateral absence of superior cornua.



Superior cornua connected to the thyroid laminae with a fibrous band (non fusion)



Hyoid bone fused with thyroid superior cornua.

Figure 12: Other variations

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Discussion

In this study several anatomical variations were identified in relation to the hyoid bone and the thyroid cartilage. Some such variations were correlated with the age and the sex. The study showed variations in the fusion of the greater horn of the hyoid with its body. The right side showed fusion more frequently than left side and this finding had been previously observerd similarly by other researchers. [(2)] The variations of the fusion are considered by some authors to be important in forensic investigations when determining the age and the gender of the victims. [(12)] In contrary to that, in our study a significant correlation between the fusion of the greater horn of the hyoid to its body and the age could not be established. The fusion of the greater horn was very variable and non-fusion was fairly common even among the elderly age groups. In the 61-70 year age group, non-fusion was 37.5%. Within the 71-80 year age group and 81-90 year age group, the percentage of non-fusions were 40% and 28.57% respectively. Most of the specimens of the hyoid bone found in the current study had bilateral lesser horns. Absence of a lesser horn on one side is relatively an uncommon finding according to our study. These results tally well with other comparative studies. [(2)] Since the hyoid bone is a midline structure, its symmetry has an anatomical significance. According to the findings of the current research, the lesser horns of the hyoid bone were symmetrical in 78.43% of the cases. This re-confirms the finding of some previous studies. [(13)] [(14)]

The direction of the greater horns of the hyoid principally determines the shape of the hyoid bone. As stated above, three main variations of the shape were identified in our study according to the direction of greater horn as parallel (9.8%), convergent (18.6%) and divergent (71%). A similar study done in Greece during 1989 had found variations of the shape of hyoid in relation to the direction of the greater horns with comparatively similar findings. [(15)]

The findings of our study indicate a great variation in the presence of triticeous cartilages in relation to the superior cornua of the thyroid cartilage. We found the overall prevalence of the triticeous cartilages in our study population to be 63%. This finding is supported by one previous study which observed that the prevalence of triticeous cartilages is around 65% in Japanese populations. (16) Contrasting results have also been reported in two Western studies. In one of the above studies, among 86 dissected cadavers, a prevalence rate of 33% was noted. In the other study which was limited to 40 cadavers, the prevalence of triticeous cartilages was estimated as 30%. [(17)] [(14)]. The difference in the findings may reflect that the prevalence of triticeous cartilages may have an ethnic impact. In South East and Far East Asian populations the prevelance tend to be higher than in the Western populations. Therefore, a multi-centred study covering population sub-types across the globe to investigate the ethnic variations in the prevalence of triticeous cartilages would be an interesting area for further research.

Anatomical variations of the hyoid-thyroid complexes are important in forensic pathological interpretations. There are some anatomical variations in this important region of the neck which might be misinterpreted as injuries. [(18)] [(2)] The presence of triticeous cartilages, for example, could be mistaken for a fracture of the superior cornua of the thyroid cartilage. The presence of accessary bones, fusion or ankylosis of the greater horn with the body of the hyoid, fusion of the

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superior cornua of the thyroid with the body of the hyoid bone, unilateral or bilateral absence of greater horns of hyoid or superior cornua of thyroid, unilateral or bilateral elongation of the lesser horns, absence of greater horns of the hyoid and superior cornua of the thyroid and presence of fibrous bands among those structures etc. are some such noteworthy variations. Therefore, when conducting an autopsy of a person died due to fatal pressure on the neck as in hanging, manual strangulation or when other pathological conditions are expected in and around the neck such as carcinomas or perforating injuries (including firearm injuries) an understanding of the standard anatomy of this region as well as the possible variations (as mentioned above) would prove to be of immense assistance for accurate interpretation of gross anatomical and radiological findings. [(6)]

In a retrospective study done in Netherland using 284 postmortem examination findings of deaths due to different forms of pressure on the neck, it was found that only 20% had fractures of the hyoid bone and fractures of the thyroid cartilage were twice as common as in the hyoid, amounting to 40%. [(18)]. In our study, out of 241 cases there were only 11 cases with fatal pressure on the neck (10 due to suicidal hanging and 01 due to homicidal ligature strangulation) and none had laryngeal skeletal injuries. This is in keeping with the gnereal forensic understanding that hanging leads to minimal internal injuries. The major difference between our study and the one conducted in 2020 lies in the study population: our one is based on all adult postmortems out of which only 11 being deaths due to fatal pressure on the neck while the 2020 study is based purely on deaths due to fatal pressure on the neck. Such studies are more informative for the study and interpretation of laryngeal trauma in deaths due to neck violence while our study is more informative in the understanding of anatomy and its variations in the region. A study conducted by Graham in 2016 showed that a substantial pressure is needed for the causation of damage to hyoid or thyroid and that the death could occur due to other mechanisms well before the laryngeal skeleton is damaged. This study also showed that hyoid bone fractures are less common than thyroid cartilage fractures. These findings are in keeping with our results as well as the results of the 2020 study based on 284 fatal cases. [(19).]

Conclusion

The study was conducted using 241 adult cadavers subjected to medico-legal postmortem examination in the JMO's office at Colombo South Teaching Hospital, Kalubowila, Sri lanka. Several anatomical variations were identified in the hyoid thyroid complexes. There correlations to the age and sex were analyzed. According to the findings there was no significant correlation between the fusion of the greater horn with the body of the hyoid and advancement of age. In 13% of the cases, lesser horns were absent at least on one side. In 80% of the cases, lesser horns were symmetrical. An acute angle between two thyroid laminae was commoner among males. Triticeous cartilages were present in 63% of the population and this was more in males than in females. Sri Lankan average for the length of the superior cornua of the thyroid for males was 16.63 mm and for females it was 13.28mm.

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Recommendations

A more extensive multi-centre study should be carried out to find out the correlation between above mentioned anatomical variations and their effects on post-mortem findings in cases of fatal pressure on the neck. Ethnic and geographic variations of the hyoid-larynx complex could be appreciated in the light of more widespread research.

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