IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 19, Issue 8 Ser.11 (August. 2020), PP 15-20
www.iosrjournals.org

Tracheal Buckling Phenomenon (Lateral Deviation) – A Radio-Anatomical Study

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***Abstract**:*
***INTRODUCTION:** Buckling of the tracheal air column at or just above the thoracic inlet on frontal chest roentgenograms(radiographs) of infants and younger children are commonly seen and is a normal phenomenon well known to pediatric radiologists. Normally observed in younger age groups and progressively reorients itself back to non-buckled position.*
***AIMS AND OBJECTIVE:** This study is a normal anatomical study of the position of the trachea in various age groups using radiographs. The main objectives of this study include the evaluation of incidence of buckling of trachea in the pediatric age group, determining its causes based on comparative study by review of literature and assessing its clinical significance.*
***MATERIALS AND METHODS** – Studying the various Radiographs by manual and software methodology (Software used – HOROS) and notifying the buckling of trachea. This study Involves the South Indian Population and radiographs that were considered as normal and without any known or identifiable pathology.*
***RESULTS** –An 80%incidence of lateral buckling phenomenon in age group below 1yr, 36% (2y/o) and 8.3%(3y/o) was noted after which the percentage of buckling was nil (0%). Major buckling effect is observed in pediatric age groups in the age up to 3 years and decreases over the years becoming nil by the latter half of the first decade and into the following years as well.*
***CONCLUSION –** Lateral Deviation of Trachea at thoracic inlet may occur normally in infants and children up to 5 years and should not be a cause for concern. The displacement is nearly always to the side opposite the aortic arch which is the major probable cause but not the only cause, other possible contributing factors are made in comparison as well.*
Keywords
- ***Tracheal Buckling , Paediatric , Radiograph***

Date of Submission: 07-08-2020 Date of Acceptance: 21-08-2020

I. Background

The upper airway is a vital part of the respiratory tract and consists of the nose, paranasal sinuses, pharynx, larynx, and extra-thoracic trachea. The structural complexity of the upper airway reflects its diverse functions, which include phonation, olfaction, humidification and warming of inspired air, preservation of airway patency, and protection of the airways. The paediatric airway is markedly different from the adult airway. These differences are most dramatic in the infant's airway and become less important as the child grows—the upper airway assumes the characteristics of the adult airway by approximately 8 years of age.

The concern lying regarding this work is the concept of TRACHEAL DEVIATION also known as the BUCKLING PHENOMENON. Buckling of the tracheal air column at or just above the thoracic inlet on frontal chest roentgenograms(radiographs) of infants and younger children are commonly seen and is a normal phenomenon well known to pediatric radiologists. Normally observed in younger age groups and progressively reorients itself back to non-buckled position. This study is a normal anatomical study of the position of the trachea in various age groups using radiographs to understand its variations and reason out with literature-in-proof for its causes.

Disorders of the large airways occur frequently in the paediatric population. Many pose a risk of life-threatening airway obstruction and respiratory distress, and thus, early recognition is essential. Combined with physical and laboratory findings, imaging plays a key role in the assessment, from diagnosis to preoperative planning. Whereas in children under 5 years of age, lateral deviation of the trachea may occur normally and should not be misconstrued as pathological . This phenomenon is believed to be caused by the relatively long tracheal length with respect to the child's short neck and rib cage, and typically occurs at or just superior to the thoracic inlet opposite to the side of the aortic arch. Other common normal variants include anterior tracheal buckling and retropharyngeal soft tissue widening during expiration and neck flexion, findings that may mimic a retropharyngeal abscess . The purpose of this study helps us to understand the multiple reasons as to why this phenomenon occurs and obtain a better anatomical and clinical-imaging significance of this phenomenon .

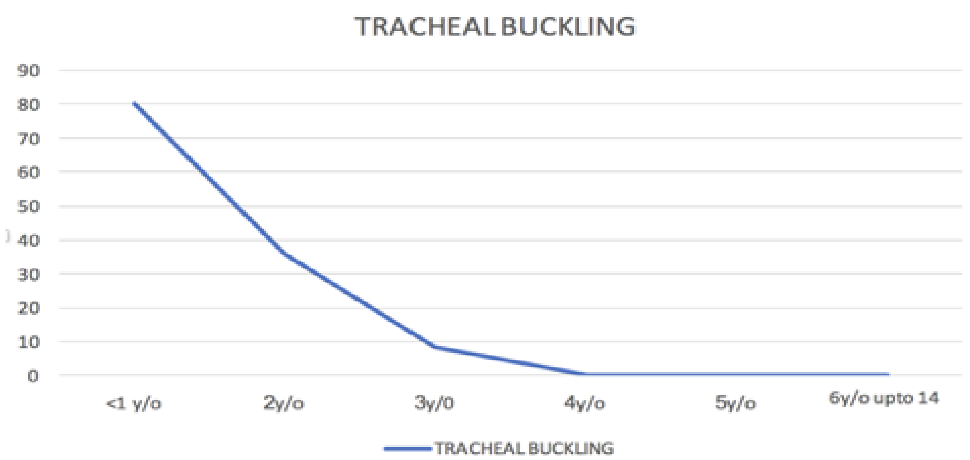
II. Objectives and Methods

To statistically show the buckling phenomenon occurrence in the pediatric age group from 1- 14 years of age .To understand the reason behind this phenomenon and its proposed theories using literature-in-proof and existing data for comparison.
A total of 180 paediatric radiographs(i.e below the age group of 14y/o) were taken during routine procedures and were studied thoroughly for the phenomenon of tracheal buckling.
The Digital Imaging and Communications in Medicine (DICOM) -HOROS software had been used for analysis and clear imaging of all the radiological scans.

III. Results

AGE (in years)	TOTAL NO. OF CASES	NO. OF CASES WITH BUCKLING	PERCENTAGE OF INCIDENCE
1	5	4	80%
2	11	4	36%
3	12	1	8.3%
4	8	-nil-	0%
5	19	-nil-	0%
6	19	-nil-	0%
7	18	-nil-	0%
8	17	-nil-	0%
9	9	-nil-	0%
10	18	-nil-	0%
11	10	-nil-	0%
12	23	-nil-	0%
13	6	-nil-	0%
14	5	-nil-	0%
TOTAL	180	9	5%

Table 1.0 Data Tabulation for the presence of tracheal buckling in 180 paediatric radiographs



Graph 1.0 Graphical representation of the above tabulated data to show the rate of incidence of the phenomenon

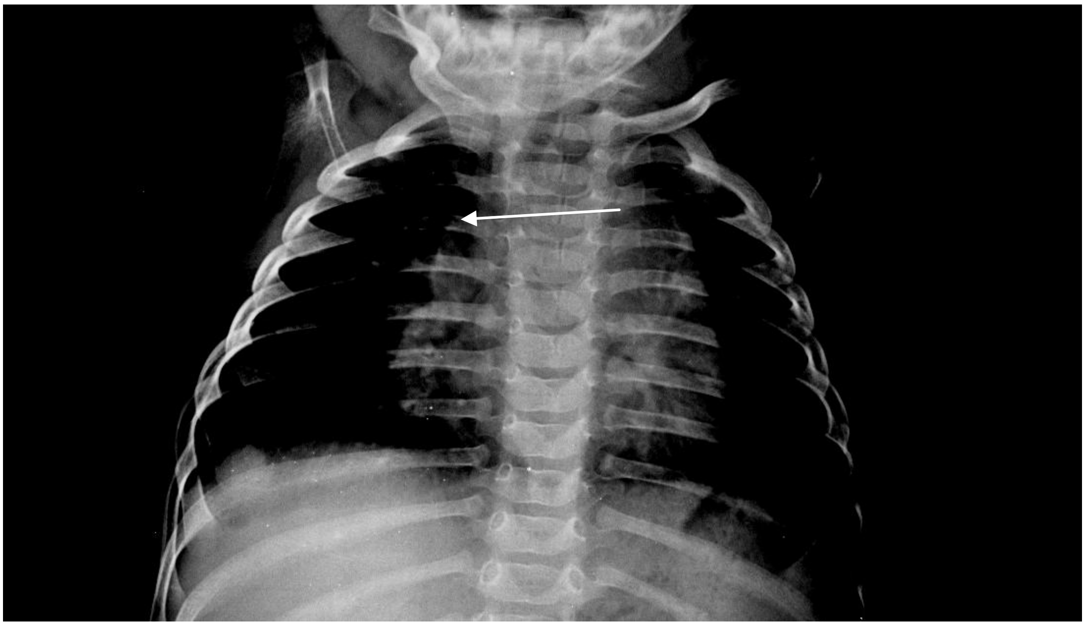


Figure 1.0 The CXR showing the phenomenon of tracheal buckling in a child of 2 years old .

IV. Discussion

The possible reasons and explanations of TRACHEAL BUCKLING IN PAEDIATRICS PATIENTS are as follows

1.Actual positioning along with Arch of Aorta(AOA) .
2.Tracheal Growth Rate
3.Difference between infant and adult trachea .
4.Thymus descendance .
5.Embryology and Growth spurts of trachea , larynx and arch of aorta .
6.Neck length consideration .
7.Errors in imaging

4.1.. The normal relation of between the arch of aorta and the tracheal tube could also point to another understanding In infants, the site of the aortic arch is frequently inferred from the position of the intrathoracic trachea. In a study by J. L. Strife, J. Matsumoto, G. S. Bisset III & R. Martin they retrospectively reviewed the plain frontal chest radiographs of 72 patients with cyanotic congenital heart disease and right aortic arch documented by cardiac catheterization. In infants, the position of the trachea was variable: 47% had the trachea on the right, 33% had the trachea midline and in 7% the trachea was on the left.[1,2] As the child grows, the aortic arch progressively indents the trachea, and the descending aorta is better visualized. Since the position of the trachea in infants with right aortic arch is variable, one must be cautious in inferring the site of the aortic arch by the position of the trachea. [2]The understanding from this study helps us counter understand the change in aortic arch initially that imposes a lateral pressure on the soft cartilaginous infantile trachea causing the buckling which progressively disappears due to strengthening of tracheal cartilages over the due course of time and returns the aorta to a lateral position over the bronchus .

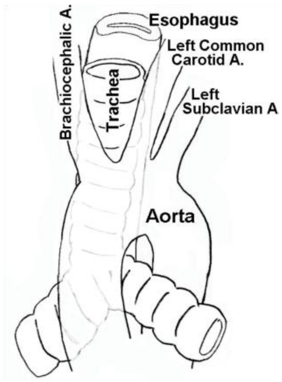


Figure 2.0 – Sketch of the normal relations of the arch of aorta (Great vessels) with the Trachea

4.2. Initially, the AP diameter is slightly greater than the transverse. Gradually, as the child grows, the adult configuration emerges. At first, the trachea is funnel-shaped. Later, the discrepancy between the sub cricoid area and the carina gradually diminishes, and the tracheal lumen changes from the cylindrical to the more adult-shaped ovoid form. The trachea stops growing in females at around age 14 years, but in males, it continues to enlarge in cross-section but not in length. This differential growth rate could possibly reason out the feature of buckling[3]

In a study of Normal growth and development of the trachea by MICHAEL P WAILOO, JOHN L EMERY From the Department of Histopathology ,Children's Hospital, Sheffield they found the trachea to be funnel shaped in the newborn, wider at the top than at the bottom, becoming marginally more cylindrical during the first five Years after birth . During this period of differential growth ,the ratio of cartilage to muscle remains constant, so that the rigidity of the wall is maintained. This contradicts the explanation to what we are trying to reason out for but due to the multiple errors in methodology of this research and its limitations we can restricts its usage into this discussion[4]

4.3. Next understanding the Anatomic features that differ between children and adults include-
(1) a proportionally larger head and occiput (relative to body size), causing neck flexion and leading to potential airway obstruction when lying supine;
(2) a relatively larger tongue, decreasing the size of the oral cavity;
(3) decreased muscle tone, resulting in passive obstruction of the airway by the tongue;
(4) a shorter, narrower, horizontally positioned, softer epiglottis;
(5) cephalad and anterior position of the larynx;
(6) shorter, smaller, narrower trachea; and
(7) funnel-shaped versus cylindrical airway, such that the narrowest portion of the airway is located at the level of the cricoid cartilage

These differences could possibly lead to the understanding that as the age advances the growth of structure and change in shape of the trachea could possibly be the reason for the decrease in the incidence of the buckling phenomenon .

4.4. During embryogenesis and in the early stages of life, the thymus is a crucial organ for the generation of the T cell repertoire. Under normal circumstances, the thymus commences involution soon after birth, and this involution correlates with the capacity to export mature T cells to the periphery. Hormones, cytokines, and neurotransmitters all play a role in this age-associated process, but the reasons for and mechanisms of this involution remain unknown. Apart from physiological conditions that change throughout life and govern age-related thymus evolution, random states and events provoked by intrinsic or extrinsic factors can induce either thymus involution, as in reversible transient thymic hypoplasia, or thymic hyperplasia[4]. The age-associated involution, unlike transient involutions, follows a regular pattern for all individuals, though there are clear differences between the sexes. Nevertheless, even the age-associated involution seems to be reversible, raising the possibility of therapeutic strategies aimed at enhancing thymus function in the elderly. Based on when the involution occurs or if there are hyperplasia due to physiological responses , this might provide a lateral pressure as well on the trachea if it is significant , this is a rare but possible suggestion for this phenomenon.[5]

4.5. The Development of the Human Trachea[6] could also help us to gain an insight in the phenomenon of buckling .Human development is divided into prenatal and postnatal periods. The prenatal period is further subdivided into 2 periods, the embryonic and foetal periods. The embryonic period (first 8 weeks after conception) is divided into 23 stages according to the Carnegie system. Each specific stage is defined by specific morphologic criteria.[6,7]

Graph showing the embryonic period (first 6 week of life) in relation to the foetal period. The crown-rump (C-R) length of the foetus is also illustrated.

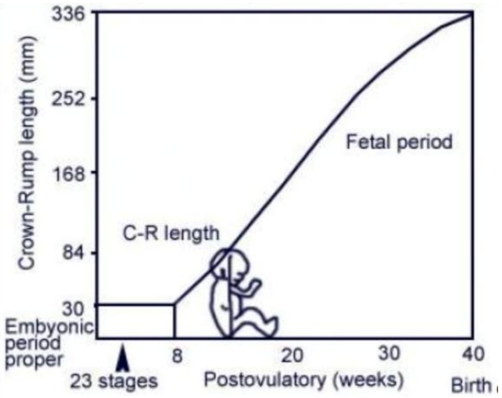


Figure 3.0 The crown-rump (C-R) length of the foetus chart [7,8]

The respiratory diverticulum (laryngotracheal diverticulum) appears between the 4^{th} and 6^{th} branchial arches. There is no evidence of identifiable respiratory system development during the first 8 stages of the Carnegie system. During stage 4 (day 20 of embryonic period), the foregut begins its appearance and the respiratory diverticulum, from which the respiratory system develops, is identified in a medial position.

At the beginning of the foetal period (30 mm crown-rump [C-R] stage), the chondrocytes are well identified within the incomplete rings of the trachea. The cartilage of the rings is hyaline. The circular shape of the trachealis muscle contains spindle-shaped myoblasts with elongated nuclei. Tracheal glands are not identifiable in the submucosa at this stage yet. During the 42-50 mm C-R stages, the circular trachealis muscle is well defined in the paries membranous and between the cartilages, but no glands are visible yet.

The circular muscle fibre of the trachealis muscle are attached to the inner surfaces of the cartilages at the 62 mm C-R stage. Some longitudinal muscle fibres are identified posterior to the circular layer. These fibres attach to the lower part of the posterior aspect of the cricoid, and caudally, they insert into the posterior surface of the carina.

At 100 mm C-R stage, both muscular layers are well indicated. However, elastic fibres, lymphocytes, and tracheal glands are not seen in the submucosa or lamina propria.

The trachea has 15-20 U-shaped rings of hyaline cartilage that are responsible for the lateral rigidity of the organ. Behind, where the "rings" are deficient, the tube is flat and is composed of bands of fibrous and elastic tissue and nonstriated muscle fibre. These tissue bands on the posterior surface of the trachea, which face the oesophagus, are capable of yielding to oesophageal dilatation resulting from the passage of food or liquid. The cartilaginous rings mechanically hold the airway open but also give it flexibility. By preventing the collapse of the conducting pathway, respiration is not impeded.

The cartilages are placed horizontally above each other, separated by narrow intervals. They measure about 4 mm in depth and 1 mm in thickness. Their outer surfaces are flattened in a vertical direction, but the internal surfaces are convex. The cartilages are thicker in the middle than at the margins. Two or more of the cartilages often unite, partially or completely, and they are sometimes bifurcated at their extremities. They are highly elastic but may become calcified in advanced life.

The first cartilage is broader than the rest and often divided at one end; it is connected by the crico tracheal ligament with the lower border of the cricoid cartilage, with which or with the succeeding cartilage, it is sometimes blended. Due to this broadening a mild form of buckling might be presented[7,8]

4.6 Short neck is an important feature of conditions like craniovertebral anomalies which have neurological complications, and of dysmorphic syndromes like Turner, Noonan, Klippel-Feil and mucopolysaccharidoses but apart from that the short neck can be a very normal physio-anatomical implication of slow growth in young ones or could also just be a slow growth rate of the particular age group and could be normal hence forth . While a lot of research has been done on abnormalities and anomalies, the basic anatomy of this phenomenon has been slipped out . The short neck is also a normal phenomenon where the growth rate of the neck length is slower as in younger age groups and because of the short neck with a longer trachea , the phenomenon of buckling might present itself on the chest radiograph in both AP or Lateral view[9].This anatomical vs abnormal short length comparison has been indirectly derived from the study by P.V. Mahajan B.A. Bharucha [9]

4.7. Issues in imaging technique - Chest radiographs are optimally performed near the end of quiet inspiration. In infants, supine anteroposterior (AP) views are satisfactory because the degree of magnification is similar compared to that of posteroanterior (PA) erect radiographs. AP views are also easier to perform. Lateral radiographs are rarely indicated. In cooperative children over 4 years of age, PA and lateral erect views are best, performed either in the seated or standing position. Evaluation for air trapping, a secondary sign of tracheobronchial foreign body obstruction, can be further evaluated with expiratory views in cooperative older children or the less technically onerous lateral decubitus views in younger uncooperative patients.[10]

Evaluation of the retro tracheal soft tissues in infants and children is difficult due to the variation in soft tissue thickness during respiration. In a study conducted, Hay noted that on the lateral roentgenogram of the neck in infants and children the trachea buckled forward during expiration. He regarded this buckling as normal and felt it was due to "crowding of the trachea during expiration", due to lax retropharyngeal tissues, and stressed the need to examine the neck in both phases of respiration. He noted that one might be misled into making a diagnosis of retropharyngeal abscess on a lateral roentgenogram of the neck if the film was obtained during the expiratory phase of respiration. While analysing the importance of lateral view , the anteroposterior view of the radiograph also shows the buckling effect as observed in this study

V. Conclusions

With our results we conclude two classical findings
1.There is a high incidence of buckling phenomenon in the group age below 4 y/o
2.There is a steep decline to an absolute null value by advancing ages
This not only supports the views of the previously done researches but adds value to the study and understanding of this phenomenon.

To conclude this understanding we can observe a huge load of literature supporting evidences for tracheal buckling phenomenon and its causative factors , to quote the most significant reason to be due to the arch of aorta but other causative factors could also cause the same .

Authors' contributions
All authors have made a joint substantial contribution to the conception and design,acquisition of data, analysis and interpretation of data and have been involved in drafting the manuscript and revising it critically for important intellectual content.

Competing Interests
Authors declare no conflicts of interest .

Acknowledgements

We would like to acknowledge the entire anatomy department in coordination with the radiology department from Bangalore Medical College and Research Association who have helped us in obtaining data for this project

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Pritik Shah, et. al. "Tracheal Buckling Phenomenon (Lateral Deviation) – A Radio-Anatomical Study." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 19(8), 2020, pp. 15-20.