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RESEARCH ARTICLE

Estimation of Radiological Age From Sternum: An Autopsy-based Study in a Tertiary Care Hospital, Visakhapatnam

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ABSTRACT

Background: Age estimation is a fundamental aspect of forensic identification, particularly in cases involving unknown deceased individuals, skeletal remains, and medicolegal investigations. The sternum is a durable bone that often withstands decomposition and can provide useful indicators for age estimation through assessment of fusion at the manubriosternal and xiphisternal joints.

Aim: To estimate radiological age from fusion status of the manubrium and xiphisternum with the body of the sternum in an autopsy population.

Methods: An autopsy-based cross-sectional study was conducted in the Department of Forensic Medicine, Andhra Medical College, Visakhapatnam. A total of 101 sterna obtained from cadavers aged 25–75 years were examined radiologically. Plain radiographs in anteroposterior and anterior oblique views were analyzed for fusion status of the manubriosternal and xiphisternal joints. Fusion was graded as non-fusion, partial fusion, or complete fusion. Age-wise and sex-wise distributions were evaluated.

Results: Among 101 sterna studied, 82 (81.2%) belonged to males and 19 (18.8%) to females. At the manubriosternal joint, non-fusion was observed in 79 (78.2%), partial fusion in 18 (17.9%), and complete fusion in 4 (3.9%) cases. At the xiphisternal joint, non-fusion was observed in 48 (47.5%), partial fusion in 30 (29.7%), and complete fusion in 23 (22.8%) cases. Fusion of the xiphisternum occurred earlier and more frequently than fusion of the manubrium. Complete xiphisternal fusion was absent below 35 years of age and became increasingly common after 45 years.

Conclusion: Radiological assessment of fusion of the sternum provides valuable information for forensic age estimation. The xiphisternal joint demonstrates earlier fusion and greater reliability compared with the manubriosternal joint. However, considerable individual variation exists, and sternum fusion should be used in conjunction with other age-estimation parameters.

Keywords: Sternum, Radiological age estimation, Forensic anthropology, Manubriosternal fusion, Xiphisternal fusion, Autopsy study.

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Introduction

One of the main goals of forensic medicine continues to be the identification of unknown deceased individuals. Identification depends heavily on age estimation, especially when skeletal remains are all that are available. While epiphyseal fusion and dental growth can be used to estimate age in children and adolescents with a fair degree of accuracy, the lack of trustworthy anatomical markers makes age assessment in adults difficult(1).

The sternum is a strong bone that often withstands stress and deterioration. An effective sign for estimating an adult's age is the fusion state of the manubrium and xiphisternum with the sternum's body. The requirement for region-specific data is highlighted by earlier research that showed significant regional and population-based heterogeneity in the timing of fusion(2).

The goal of the current study was to determine the radiological fusion state of the sternum in a Visakhapatnam autopsy population and evaluate its usefulness in forensic age assessment.

Materials And Methods

Study Design

Autopsy-based cross-sectional observational study.

Study Setting

Department of Forensic Medicine and Toxicology, Andhra Medical College, Visakhapatnam.

Study Population

Sterna obtained from medicolegal autopsies performed during the study period.

Sample Size

101 sterna.

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Inclusion Criteria

- Improper radiographic exposure.
- Cadavers with age 25 to 75 years in and around Visakhapatnam.

Exclusion Criteria

Cadavers with short stature, congenital chest wall deformities (Pectus excavatum, Pectus carinatum, etc), chest trauma (including but not limited to sternal fractures), mutilated bodies.

Study Procedure

Following autopsy, sterna were carefully removed and subjected to radiographic examination. Plain radiographs were obtained in anteroposterior and anterior oblique views. Fusion status was graded as:

Grade 0 – Non-fusion (homogeneous radiolucent gap)

Grade 1 – Partial fusion (heterogeneous radiolucency/ radiopacity) Grade 2 – Complete fusion (homogeneous radiopacity)

Data were analyzed according to age and sex distributions.

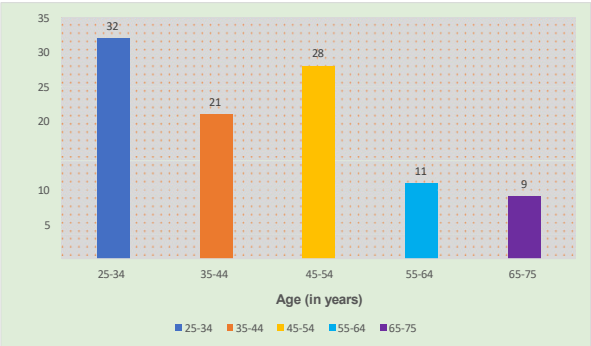

Chart 1: Age wise distribution

Results

Table 1: Age wise distribution of the sample in ten year intervals with percentage

Age in 10yr intervals	*Frequency(n)*	*Percentag e among the sample*
25-34	32	31.7%
35-44	21	20.8%
45-54	28	27.7%
55-64	11	10.9%
65-75	9	8.9%
Total	101	100.0%

Table. 2: Measures of central tendency for the collected sample

Mean	43.62
Median	44.00
Std. Deviation	13.629
Minimum	25
Maximum	75

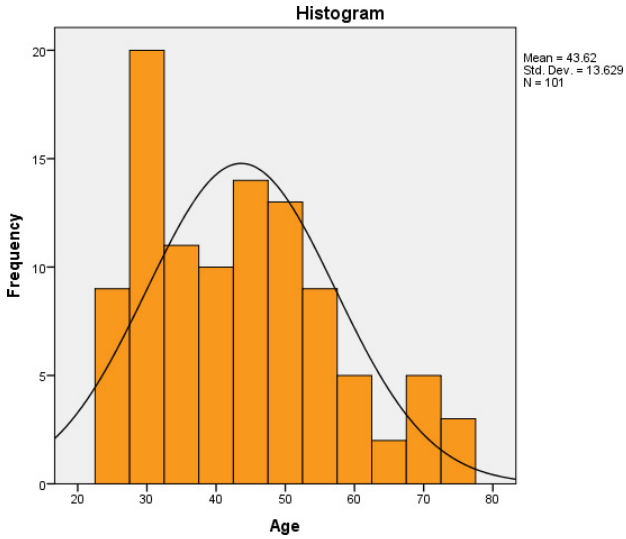

Chart 2: Histogram showing the age wise distribution of the sample along with the measures of central tendency

Sex Wise Distribution

Table. 3: Sex wise distribution of the sample

Sex	*Frequency(N)*	*Percentage*
Female	19	18.8%
Male	82	81.2%
Total	101	100.0%

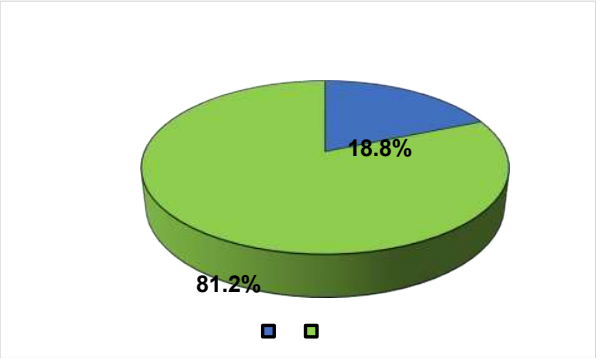

Chart. 3: Sex wise distribution of the sample

Table 4: Age along with Sex wise distribution in ten year intervals with percentage

Age in 10yr Intervals	*Male*	*Female*	*Frequency(n) in a particular Interval*
25-34	24 (23.8%)	8 (7.9%)	32 (31.7%)
35-44	17 (16.9%)	4 (3.9%)	21 (20.8%)
45-54	24 (23.8%)	4 (3.9%)	28 (27.7%)
55-64	10 (9.9%)	1 (0.9%)	11 (10.8%)
65-75	7 (6.9%)	2 (1.9%)	9 (8.8%)
Total	82 (81.2%)	19 (18.8%)	101 (100.0%)

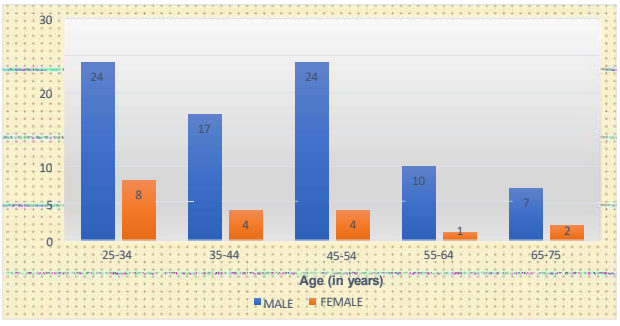

Chart 4: Age along with Sex wise distribution in ten year intervals

Table. 5: Sex wise distribution of measures of central tendency

Sex		
Female	Mean	41.16
	Median	36.00
	Std. Deviation	14.427
	Minimum	25
	Maximum	75
Male	Mean	44.20
	Median	44.50
	Std. Deviation	13.465
	Minimum	25
	Maximum	75

Table. 6: Overall distribution of status of fusion of manubrium with the body of sternum

M-b fusion status	*Frequency(n)*	*Percentage*
Non-fusion	79	78.2%
Partial fusion	18	17.9%
Complete fusion	4	3.9%
Total	101	100.0%

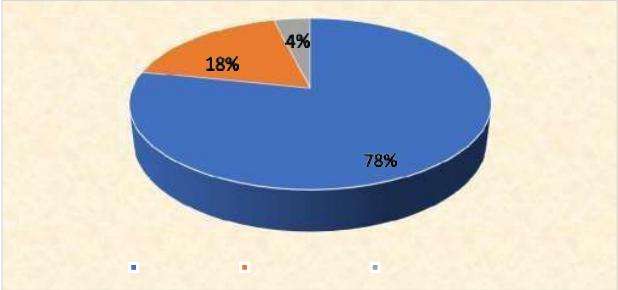

Chart 5: Overall distribution of status of fusion of manubrium with the body of sternum

Table. 7: Sex wise distribution of status of fusion of manubrium with the body of sternum

Sex	*M-b fusion status*	*Frequency (n)*	*Percentage*
Female	Non-fusion	15	78.9%
	Partial fusion	1	5.3%
	Complete fusion	3	15.8%
	Total	19	100.0%
Male	Non-fusion	64	78.0%
	Partial fusion	17	20.8%
	Complete fusion	1	1.2%
	Total	82	100.0%

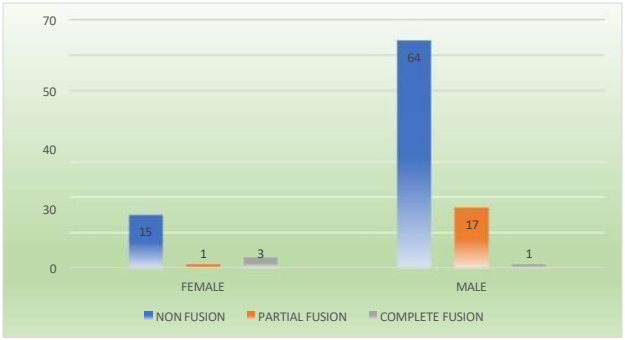

Chart 6: Sex wise distribution of status of fusion of manubrium with body of sternum

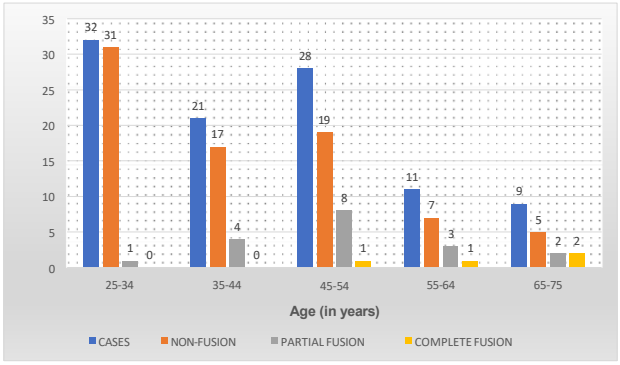

Chart. 7: Age wise distribution of status of fusion of manubrium with the body of sternum

Table. 8: Age wise distribution of status of fusion of manubrium with the body of sternum

Age interval	*M-b fusion status*	*Frequency (n)*	*Percentage*
25-34	Non-fusion	31	96.8%
	Partial fusion	1	3.2%
	Complete fusion	0	0%
	Total	32	100.0%
35-44	Non-fusion	17	81%
	Partial fusion	4	19%
	Complete fusion	0	0%
	Total	21	100.0%
45-54	Non-fusion	19	67.9%
	Partial fusion	8	28.6%
	Complete fusion	1	3.6%
	Total	28	100.0%
55-64	Non-fusion	7	63.6%
	Partial fusion	3	27.3%
	Complete fusion	1	9.1%
	Total	11	100.0%
65-75	Non-fusion	5	55.6%
	Partial fusion	2	22.2%
	Complete fusion	2	22.2%
	Total	9	100.0%

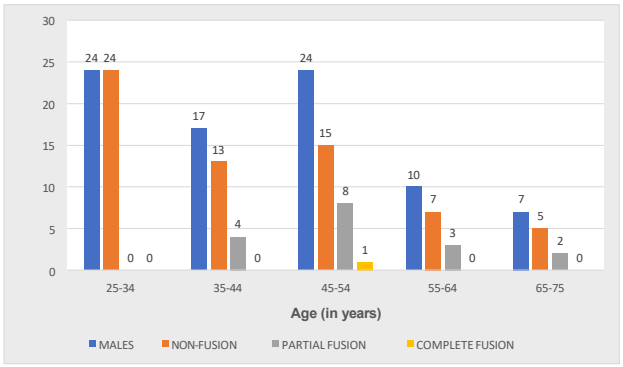

Chart 8: Age along with male sex wise distribution of status of fusion of manubrium with the body of sternum

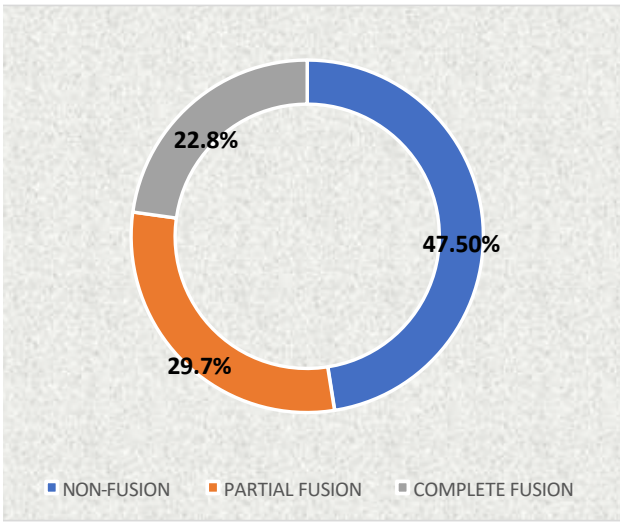

Chart.10: Overall distribution of status of fusion of xiphisternum with the body of sternum

Table 9: Age along with sex wise distribution of status of fusion of manubrium with the body of sternum

Age in Intervals	*Non-fusion*			*Partial Fusion*			*Complete Fusion*			*Frequency (n)*
	F	*M*	*F + m*	*F*	*M*	*F + m*	*F*	*M*	*F + m*	
25-34	7	24	31	1	0	1	0	0	0	32
35-44	4	13	17	0	4	4	0	0	0	21
45-54	4	15	19	0	8	8	0	1	1	28
55-64	0	7	7	0	3	3	1	0	1	11
65-75	0	5	5	0	2	2	2	0	2	9
Total	15	64	79	1	17	18	3	1	4	101

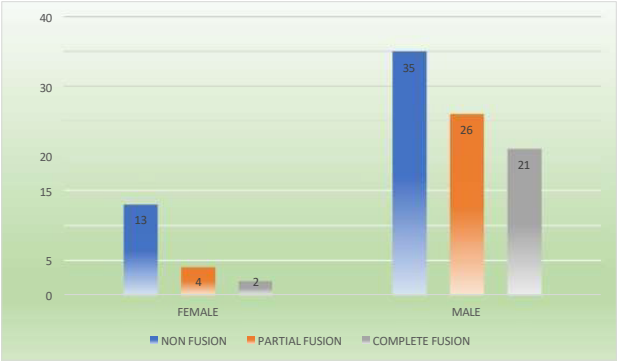

Chart 11: Sex wise distribution of status of fusion of xiphisternum with the body of sternum

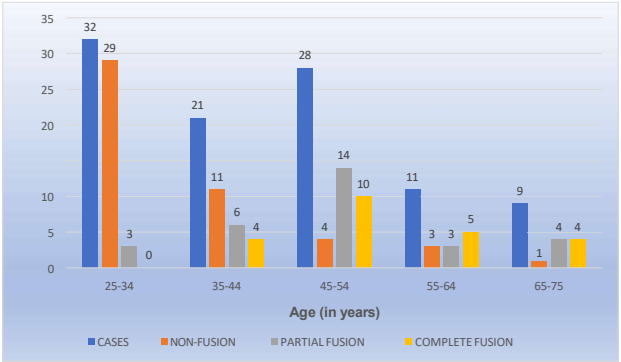

Chart. 12: Age wise distribution of status of fusion of xiphisternum with the body of sternum

Discussion

In this work, the fusion status of the manubriosternal and xiphisternal joints was evaluated in order to determine the value of radiological evaluation of the sternum for forensic age assessment. X-ray imaging was used to examine 101 sternum samples taken from medicolegal autopsies of people between the ages of 25 and 75. Based on radiological appearance, fusion status was divided into three categories:

Table 10: Overall distribution of status of fusion of xiphisternum with the body of sternum

X-b fusion status	*Frequency(n)*	*Percentage*
Non-fusion	48	47.5%
Partial fusion	30	29.7%
Complete fusion	23	22.8%
Total	101	100.0%

Table 11: Sex wise distribution of status of fusion of xiphisternum with the body of sternum

Sex	*X-b fusion status*	*Frequency (n)*	*Percentage*
Female	Non-fusion	13	68.4%
	Partial fusion	04	21.1%
	Complete fusion	02	10.5%
	Total	19	100.0%
Male	Non-fusion	35	42.7%
	Partial fusion	26	31.7%
	Complete fusion	21	25.6%
	Total	82	100.0%

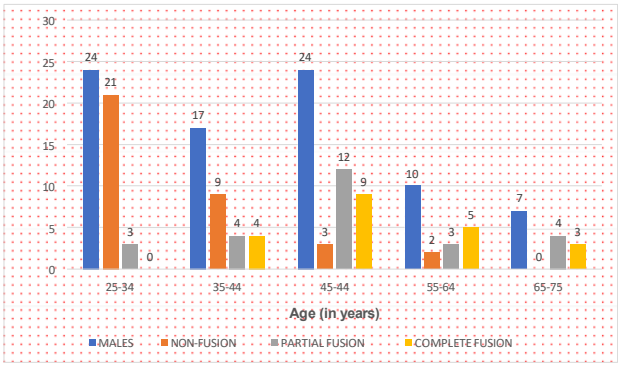

Chart 13: Age along with male sex wise distribution of status of fusion of xiphisternum with the body of sternum

Table. 12: Age wise distribution of status of fusion of xiphisternum with the body of sternum

Age interval	*X-b fusion status*	*Frequency(n)*	*Percentage*
25-34	Non-fusion	29	90.6%
	Partial fusion	3	9.4%
	Complete fusion	0	0%
	Total	32	100.0%
35-44	Non-fusion	11	52.4%
	Partial fusion	6	28.6%
	Complete fusion	4	19%
	Total	21	100.0%
45-54	Non-fusion	4	14.3%
	Partial fusion	14	50.0%
	Complete fusion	10	35.7%
	Total	28	100.0%
55-64	Non-fusion	3	27.3%
	Partial fusion	3	27.3%
	Complete fusion	5	45.5%
	Total	11	100.0%
65-75	Non-fusion	1	11.1%
	Partial fusion	4	44.4%
	Complete fusion	4	44.4%
	Total	9	100.0%

non-fusion, partial fusion, and complete fusion(3). Males predominated in the studied population (81.2%) as opposed to females (18.8%). The age groups of 25–34 years old accounted for the bulk of instances, followed by 45–54 years old and 35–44 years old. This distribution made it possible to see how sternal fusion changed with age throughout a broad age range(4).

The most frequent finding in the analysis of the manubriosternal joint was non-fusion. Only 3.9% of the 101 sterna showed full fusion, whereas 78.2% showed

Rad. 1: Radiograph in Antero-posterior & right oblique anterior views of a 19 year old sternum taken as control, showing the sternebrae in the process of fusion and clear gap (homogenous radiolucency) between manubrium, the body and xiphisternum (white arrows)

non-fusion and 17.9% showed partial fusion. These results suggest that even in older people, total fusion of the manubrium with the sternum's body is somewhat rare. Significant variation in the timing of manubriosternal fusion is suggested by the persistence of non-fusion in a significant percentage of elderly people. Age-wise analysis showed that as people aged, partial and complete fusion increased while non-fusion gradually decreased(5). Nearly all people in the youngest age group (25–34 years old) showed non-fusion, while the age group with the highest percentage of full fusion was 65–75 years old. More over half of the people in the oldest age group continued to exhibit non-fusion despite this trend. This age group overlap emphasises how unreliable

Table 13: Age along with sex wise distribution of status of fusion of xiphisternum with the body of sternum

Age in Intervals	*Non-fusion*			*Partial Fusion*			*Complete Fusion*			*Frequency (n)*
	F	*M*	*F+m*	*F*	*M*	*F+m*	*F*	*M*	*F+m*	
25-34	8	21	29	0	3	3	0	0	0	32
35-44	2	9	11	2	4	6	0	4	4	21
45-54	1	3	4	2	12	14	1	9	10	28
55-64	1	2	3	0	3	3	0	5	5	11
65-75	1	0	1	0	4	4	1	3	4	9
Total	13	35	48	4	26	30	2	21	23	101

Rad. 2: Radiograph in Antero-posterior & right oblique anterior views of a 74 year old female sternum, showing homogenous radio-opacity (white arrows) at the manubriosternal and xiphisternal joints. Note the continuity of the trabeculae at both the joints indicating complete fusion.

Rad. 3: Radiograph in Antero-posterior & right oblique anterior views of a 48 year old male sternum showing partial fusion (white arrows) at the manubriosternal joint. Note the position and irregular shape of the xiphisternum (black arrows)

manubriosternal fusion is when used as the only criterion for estimating age(6).

Non-fusion predominated regardless of sex, according to sex-wise analysis, which revealed similar patterns in both males and females. It was discovered that females had a somewhat earlier mean age of fusion onset than males. However, this observation's power is limited by the small number of female samples. Only a few number

Rad. 4: Radiograph in Antero-posterior & right oblique anterior views of a 54 year old female sternum showing complete fusion (white arrows) at the xiphisternal joint. Note that the manubrium is in a state of non-fusion with the body of sternum (red arrows)

of cases resulted in complete fusion, highlighting the anatomical landmark's heterogeneity. The results of the study indicate that although sternal fusion shows an age-related trend, its accuracy as an independent age predictor is diminished by the degree of overlap among various age groups. However, because radiographic evaluation of the sternum is non-destructive, reasonably easy, and can yield supporting evidence when paired with other age-estimation techniques, it continues to be a valuable supplement in forensic practice(7).

In conclusion, forensic age estimation greatly benefits from radiographic assessment of the sternum. Compared to the manubriosternal joint, the xiphisternal joint typically offers more consistent and early fusion patterns, making it a more reliable indicator of age. On the other hand, complete manubriosternal fusion is rare and very variable, which restricts its use in forensics on its own(8). As a result, sternum fusion shouldn't be used alone. Its results should be evaluated in combination with other skeletal, dental, and radiological indications of age for increased precision and dependability. A multidisciplinary strategy like this can reinforce medicolegal judgements and increase the accuracy of forensic age estimation(9).

Conclusion

Radiological assessment of the sternum is a useful supplementary tool for forensic age estimation. The current study showed that manubriosternal fusion gradually increases with age; nevertheless, only a tiny percentage of

people showed complete fusion, and non-fusion persisted even in older age groups. The reliability of manubriosternal fusion as an independent indicator of chronological age is limited by these data, which show significant diversity in its timing and pattern. Significant overlap between various age groups lowers the accuracy of age assessment based only on sternal fusion, even though age-related trends were clearly visible. To increase the precision and dependability of forensic age estimation, radiological assessment of the sternum should be combined with other skeletal, dental, and radiological data. To get reliable medicolegal conclusions, a multidisciplinary approach is still necessary.

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