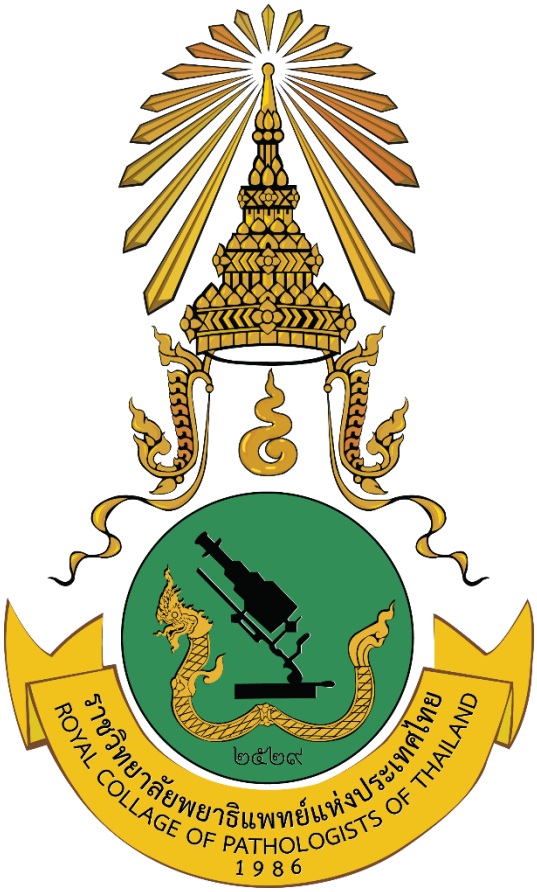
ASIAN ARCHIVES OF PATHOLOGY

THE OFFICIAL JOURNAL OF THE ROYAL COLLEGE OF PATHOLOGISTS OF THAILAND



Volume 8
Number 2
April – June 2026

INDEX COPERNICUS INTERNATIONAL

Print ISSN: 1905-9183
Online ISSN: 2673-0499

EDITORIAL BOARD

ABOUT THE JOURNAL

Aims and Scope

Asian Archives of Pathology (AAP) is an open access, peer-reviewed journal. The journal was first published in 2002 under the Thai name "วารสารราชวิทยาลัยพยาธิแพทย์แห่งประเทศไทย" and English name "Journal of the Royal College of Pathologists of Thailand". The journal is a publication for workers in all disciplines of pathology and forensic medicine. In the first 3 years (volumes), the journal was published every 4 months. Until 2005, the journal has changed its name to be "Asian Archives of Pathology: The Official Journal of the Royal College of Pathologists of Thailand", published quarterly to expand the collaboration among people in the fields of pathology and forensic medicine in the Asia-Pacific regions and the Western countries.

The full articles of the journal are appeared in either Thai or English. However, the abstracts of all Thai articles are published in both Thai and English languages. The journal features letters to the editor, original articles, review articles, case reports, case illustrations, and technical notes. Diagnostic and research areas covered consist of (1) **Anatomical Pathology** (including cellular pathology, cytopathology, haematopathology, histopathology, immunopathology, and surgical pathology); (2) **Clinical Pathology (Laboratory Medicine)** [including blood banking and transfusion medicine, clinical chemistry (chemical pathology or clinical biochemistry), clinical immunology, clinical microbiology, clinical toxicology, cytogenetics, parasitology, and point-of-care testing]; (3) **Forensic Medicine (Legal Medicine or Medical Jurisprudence)** (including forensic science and forensic pathology); (4) **Molecular Medicine** (including molecular genetics, molecular oncology, and molecular pathology); (5) **Pathobiology**; and (6) **Pathophysiology**.

All issues of our journal have been printed in hard copy since the beginning. Around the late 2014, we developed our website (www.asianarchpath.com) in order to increase our visibility. We would like to acknowledge that our journal has been sponsored by the Royal College of Pathologists of Thailand. We have the policy to disseminate the verified scientific knowledge to the public on a non-profit basis. Hence, we have not charged the authors whose manuscripts have been submitted or accepted for publication in our journal.

On the other hand, if any authors request a printed copy of the journal issue containing the articles, each of the copied journals costs 450 bahts for Thai authors and 30 United States dollars (USD) for international authors.

Publication Frequency

Four issues per year

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MANUSCRIPT REVIEWERS

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ORIGINAL ARTICLE

Study of Normal Internal Organ Weights Correlated to Body Weight, Height, and Sex in Autopsied Thai Children: Data from Institute of Forensic Medicine of Police General Hospital

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Conflict of interest: The authors declare that they have no conflicts of interest with the contents of this article.

Submitted: *15 February 2025*
Accepted: *24 April 2025*
Published: *1 June 2026*

Abstract

Background: The weight of internal organs plays a critical role in autopsy assessments for determining the cause of death. However, no prior study has analyzed organ weight data in Thai children under 16 years of age.

Objective: The primary objective is to study the internal organ weights of Thai children under the age of 16.

Materials and Method: This retrospective analytical study reviewed 215 autopsy cases (137 males, 78 females) conducted at a single center between 2020 and 2023. The organs evaluated included the brain, heart, lungs, liver, kidneys, and spleen.

Results: The study population ranged in age from 0 to 15 years. The mean organ weights (grams) for males and females, respectively, were as follows brain 1026.55/911.22, heart 138.28/100.17, right lung 223.39/161.76, left lung 198.88/151.28, liver 681.54/549.62, right kidney 62.13/50.28, left kidney 63.02/50.95, and spleen 65.78/51.29.

Conclusion: A statistically significant correlation was observed between body weight, height, and internal organ weights in both sexes, except for the heart in females aged 0–11 months. Additionally, male subjects exhibited consistently higher organ weights than female subjects

Keywords: Organ Weight, Body Weight, Body Height, Autopsy, Thai Children

Introduction

The determination of normal internal organ weights plays a crucial role in forensic medicine, as it can provide valuable insights into certain pathological conditions and, in some cases, the cause of death. The pathological examination of internal organs can be conducted both macroscopically and microscopically. The primary objective of an autopsy is to ascertain the cause of death. Establishing reference data on the normal weights of internal organs in Thai pediatric deceases would significantly enhance the accuracy and reliability of identifying organ abnormalities. Even in the absence of observable macroscopic pathological changes, deviations in organ weight from the normal range relative to age, height, or body weight may warrant further histopathological examination.

Currently, data on the normal internal organ weights of Thai children under the age of 16 remain scarce. Consequently, no established reference values exist for this population. A review of existing research in Thailand reveals that studies on normal internal organ weights have primarily focused on individuals aged 15 years and older. Findings from forensic autopsies indicate that internal organ weights exhibit a correlation with body weight, height, and age[1]. A review of international research indicates that findings are consistent with these observations. Notably, autopsy studies conducted on the Indian population by Deepika et al.[2] and on the Iranian population by Gholamzadeh S et al.[3] have reported similar results.

The primary objective of this study is to investigate the normal weights of internal organs in Thai pediatric deceases under the age of 16. The secondary objective is to examine the correlations between internal organ weight and height, body weight, and sex.

Materials and Methods

The data for this study were retrospectively obtained from autopsy records conducted between 2020 and 2023. No personally identifiable information, such as names or corpse identification numbers, was recorded, ensuring that the research data remain untraceable to specific individuals. The primary objective of this study is to establish reference values for the mean weights of internal organs in Thai pediatric deceases under the age of 16, providing a reliable foundation for academic and forensic applications.

Prior to the commencement of this study, formal approval was obtained from the Commander of the Institute of Forensic Medicine, Police General Hospital. Additionally, the

study received ethical clearance from the Full Board Review Sub-Committes of the Police General Hospital.

Between 2020 and 2023, a total of 365 pediatric deceases under the age of 16 underwent autopsy at the Institute of Forensic Medicine, Police General Hospital. Given the defined population size, the sample size was calculated using the Taro Yamane formula to ensure statistical validity.

Utilizing the Taro Yamane formula, the required sample size was calculated to be 190.85 cases. However, from a total population of 365 cases, 150 were excluded based on predefined exclusion criteria. The excluded cases comprised deceases exhibiting gross (macroscopically) or histopathological (microscopically) abnormalities of internal organs, non-Thai nationals, infants with unknown gestational age or preterm births, decomposed bodies, deceases with missing organs or body parts, and burnt bodies, as these conditions may alter the normal weight of internal organs.

Consequently, the final population meeting the inclusion criteria consisted of 215 cases. To ensure the reliability and robustness of the findings, the final sample size was set at 215 cases, encompassing all eligible subjects.

Subjects included in this study were required to be preserved in mortuary refrigerator within 24 hours postmortem and must not meet any exclusion criteria. For each case, body height was measured from the vertex to the heel using a measuring tape with centimeter precision. Body weight and internal organ weight were recorded using a digital scale with an accuracy of three decimal places. The digital scale had undergone standardized calibration to ensure measurement accuracy before use. The internal organs examined in this study included the brain, heart, lungs, liver, kidneys, and spleen.

The documentation and recording of subjects data included sex, age, body weight, height, and internal organ weights. The data were categorized into two groups based on sex and reported according to age groups: 0–11 months and 1–15 years. The correlation between male and female groups was analyzed using the independent samples t-test to assess statistical differences.

Subsequently, the mean internal organ weights were analyzed for correlations with body weight and height using Pearson correlation analysis, stratified by sex. Finally, multiple linear regression analysis was performed, and the results were expressed in the form of a linear equation ($y = a + bx_1 + cx_2 + dx_3$), where the dependent variable (y) represents the weight of each internal organ, while the independent variables include body weight, height, sex, and age.

Results

Among the selected sample of 215 cases, there were 137 male subjects and 78 female subjects. The total number of organs analyzed was less than the sample size due to the exclusion of certain organs based on established criteria. The mean and standard deviation for body weight, height, and internal organ weights were calculated and presented for each age group and sex, specifically for the 0–11 months and 1–15 years age ranges.

In the 0–11 months age group, both male and female subjects exhibited an increasing trend in body weight, height, and internal organ weights corresponding to advancing age, reflecting typical growth and development patterns. These findings are consistent with those reported in a study conducted on infant cadavers in the United Kingdom by Pryce JW et al. [4].

Similarly, in the 1–15 years age group, both male and female subjects demonstrated a positive correlation between increasing age and the mean values of body weight, height, and internal organ weights, indicative of normal physiological growth. These results align with those observed in a study examining internal organ sizes in pediatric populations in Turkey by Bayramoğlu Z et al. [5]. The detailed results are presented in the subsequent Table 1 and Table 2.

Table 1: The Mean and Standard Deviation of Body Weight, Height, and Internal Organ Weights of Age 0–11 Months for Male and Female

Age (months)	N	Mean ± Standard Deviation (Male)								
		Body Weight	Body Height	Brain	Heart	Lung (Rt.)	Lung (Lt.)	Liver	Kidney (Rt.)	Kidney (Lt.)	Spleen
0	14	3.19 ± 0.80	50.21 ± 3.18	386.43 ± 3.65	23.36 ± 8.71	33.54 ± 11.85	26.54 ± 8.68	147.93 ± 43.63	13.43 ± 3.72	13.29 ± 3.65	12.21 ± 5.52
1	6	4.27 ± 1.32	52.50 ± 2.74	502.81 ± 92.32	27.33 ± 19.88	44.50 ± 13.66	35.67 ± 10.93	166.33 ± 52.95	16.33 ± 4.18	16.67 ± 4.80	25.17 ± 30.21
2	6	5.18 ± 0.13	58.75 ± 3.16	618.50 ± 39.15	34.50 ± 7.34	62.21 ± 6.63	49.33 ± 9.37	206.57 ± 29.53	20.86 ± 4.18	21.43 ± 2.99	30.14 ± 20.26
3	3	4.73 ± 2.60	57.17 ± 5.80	595.33 ± 182.15	27.13 ± 11.31	66.67 ± 15.57	67.33 ± 21.78	191.50 ± 40.31	13.54 ± 2.12	14.09 ± 1.41	21.23 ± 12.73
4	5	5.32 ± 1.66	59.50 ± 3.50	455.12 ± 216.07	52.08 ± 43.96	66.63 ± 27.12	49.21 ± 27.70	241.21 ± 76.55	30.30 ± 20.31	29.40 ± 15.31	29.80 ± 21.39
5	4	6.05 ± 2.19	65.03 ± 1.41	789.50 ± 106.77	60.51 ± 36.06	59.55 ± 14.85	52.50 ± 3.54	247.14 ± 39.60	26.27 ± 1.41	27.52 ± 0.71	28.59 ± 16.26
6	0										
7	3	6.85 ± 5.87	62.50 ± 13.44	590.53 ± 296.28	31.50 ± 19.09	62.50 ± 31.82	56.50 ± 26.16	198.50 ± 143.54	16.50 ± 4.95	17.15 ± 4.24	15.50 ± 13.44
8	2	7.15 ± 1.91	67.00 ± 5.66	802.07 ± 141.42	55.14 ± 21.21	115.31 ± 7.07	105.15 ± 7.07	325.03 ± 7.07	35.11 ± 7.07	32.50 ± 3.54	35.11 ± 7.07
9	1	7.31	71.22		41.06	61.13	55.31	403.41	52.19	51.13	71.23
10	1	8.52	75.31		63.11	80.22	79.07	301.28	63.20	62.29	
11	0										

Age (months)	N	Mean ± Standard Deviation (Female)									
		Body Weight	Body Height	Brain	Heart	Lung (Rt.)	Lung (Lt.)	Liver	Kidney (Rt.)	Kidney (Lt.)	Spleen
0	6	3.20 ± 1.26	48.08 ± 4.20	362 ± 40.69	21.60 ± 8.35	47.02 ± 23.28	38.40 ± 17.23	137.17 ± 38.78	11.67 ± 4.80	11.33 ± 5.72	8.83 ± 5.12
1	8	4.27 ± 0.83	54.29 ± 5.67	501.29 ± 64.40	25.21 ± 5.60	47.31 ± 14.40	38.21 ± 11.36	179.67 ± 44.09	16.77 ± 2.68	17.29 ± 5.79	13.80 ± 5.41
2	8	4.92 ± 1.56	56.17 ± 11.43	543.50 ± 42.15	36.83 ± 21.92	54.10 ± 15.50	46.33 ± 12.91	160.33 ± 66.00	22.03 ± 6.87	21.17 ± 7.57	23.07 ± 9.30
3	2	7.45 ± 0.92	61.04 ± 3.44	587.50 ± 31.82	30.09 ± 7.07	75.24 ± 7.07	55.12 ± 7.07	247.59 ± 3.54	22.52 ± 3.54	27.49 ± 3.54	32.50 ± 3.54
4	2	5.16 ± 1.47	61.11 ± 5.63	589.52 ± 105.36	37.22 ± 11.31	57.50 ± 31.82	41.50 ± 30.41	211.41 ± 9.19	25.48 ± 0.71	26.03 ± 1.41	20.44 ± 7.78
5	1	6.78	65.03	775.13	32.31	86.15	62.33	278.26	24.31	26.07	35.20
6	0										
7	1	8.92	67.50	907.25	36.19	47.22	38.08	274.04	25.14	27.10	25.17
8	0										
9	3	6.47 ± 1.01	66.67 ± 3.01	870.05 ± 22.91	61.67 ± 59.23	65.08 ± 31.22	38.33 ± 7.64	215.12 ± 42.72	20.09 ± 5.00	21.67 ± 2.89	15.03 ± 5.00
10	2	6.35 ± 3.46	68.05 ± 2.46	660.47 ± 232.64	33.08 ± 9.90	69.51 ± 14.85	73.41 ± 38.18	242.48 ± 109.66	21.11 ± 5.66	16.50 ± 4.95	19.14 ± 1.41
11	0										

Table 2: The Mean and Standard Deviation of Body Weight, Height, and Internal Organ Weights of Age 1-15 Years for Male and Female

	N	Mean ± Standard Deviation (Male)								
		Body Weight	Body Height	Brain	Heart	Lung (Rt.)	Lung (Lt.)	Liver	Kidney (Rt.)	Kidney (Lt.)	Spleen
1	10	10.36 ± 3.48	75.60 ± 9.18	974.33 ± 203.82	67.11 ± 26.13	132.59 ± 96.71	102.90 ± 73.46	427.50 ± 183.13	40.50 ± 18.60	41.20 ± 18.34	50.25 ± 28.52
2	6	13.38 ± 1.91	92.02 ± 6.13	1,176.25 ± 100.11	66.67 ± 18.35	119.29 ± 96.71	88.57 ± 46.97	349.29 ± 170.28	30.71 ± 16.94	36.67 ± 10.80	32.86 ± 22.89
3	4	14.30 ± 2.34	99.21 ± 4.36	1,186.67 ± 80.83	86.25 ± 9.46	166.25 ± 44.98	151.23 ± 50.99	585.92 ± 145.49	62.55 ± 41.93	60.03 ± 32.66	61.08 ± 16.33
4	2	14.15 ± 0.78	103.15 ± 1.41	1,275.03 ± 176.78	110.17 ± 14.14	135.15 ± 7.01	125.34 ± 21.21	550.76 ± 70.71	55.09 ± 35.36	45.31 ± 21.21	59.05 ± 28.28
5	5	16.33 ± 4.66	110.67 ± 3.51	1,102.53 ± 141.42	113.33 ± 55.08	136.67 ± 92.92	126.67 ± 92.38	563.33 ± 125.03	51.32 ± 45.83	49.84 ± 45.83	42.02 ± 26.46
6	4	20.85 ± 3.78	114.75 ± 1.26	1,313.31 ± 204.29	103.54 ± 16.33	177.50 ± 63.44	152.58 ± 62.92	660.01 ± 108.32	55.68 ± 30.00	52.04 ± 25.82	65.21 ± 17.32
7	1	19.73	122.08	1,207.52	126.18	153.18	162.31	760.87	60.21	60.00	60.37
8	0										
9	4	31.38 ± 9.15	132.51 ± 2.65	1,353.06 ± 114.89	143.33 ± 35.12	265.08 ± 57.45	237.56 ± 90.32	933.32 ± 404.15	115.31 ± 57.45	125.05 ± 66.08	126.67 ± 75.72
10	0										
11	5	37.94 ± 4.65	143.67 ± 2.08	1,382.62 ± 81.85	202.35 ± 113.14	323.32 ± 15.28	294.18 ± 17.32	846.67 ± 233.52	73.33 ± 30.55	71.31 ± 36.06	116.57 ± 80.21
12	8	45.19 ± 7.60	152.88 ± 5.57	1,305.71 ± 256.05	233.12 ± 90.37	405.82 ± 188.15	336.25 ± 132.01	1,204.11 ± 638.12	98.57 ± 37.61	83.75 ± 47.19	115.71 ± 65.79
13	4	46.63 ± 2.63	164.50 ± 1.29	1,550.19 ± 173.21	241.26 ± 48.99	397.56 ± 150.64	382.56 ± 134.26	1,1125.53 ± 253.16	97.50 ± 28.72	105.02 ± 19.15	130.12 ± 45.46
14	20	54.50 ± 6.45	166.05 ± 5.39	1,469.41 ± 121.27	256.32 ± 53.67	437.22 ± 207.07	412.11 ± 190.78	1,243.68 ± 465.86	104.21 ± 26.31	109.47 ± 29.34	123.75 ± 50.97
15	19	55.97 ± 9.83	166.48 ± 13.65	1,413.13 ± 144.81	288.84 ± 70.01	389.51 ± 123.05	344.74 ± 94.36	1,325.09 ± 379.18	113.02 ± 22.03	114.11 ± 21.37	118.89 ± 41.57

Age (years)	N	Mean ± Standard Deviation (Female)									
		Body Weight	Body Height	Brain	Heart	Lung (Rt.)	Lung (Lt.)	Liver	Kidney (Rt.)	Kidney (Lt.)	Spleen
1	8	9.68 ± 2.14	62.44 ± 25.05	868.57 ± 237.24	65.02 ± 34.52	95.71 ± 17.42	84.29 ± 20.50	395.71 ± 110.88	33.57 ± 16.51	35.71 ± 19.02	40.10 ± 19.15
2	4	10.58 ± 3.33	80.38 ± 13.24	1,032.50 ± 295.90	62.50 ± 29.86	111.25 ± 52.97	102.50 ± 57.95	423.75 ± 158.19	33.75 ± 4.79	32.50 ± 8.66	36.25 ± 22.87
3	3	10.27 ± 2.05	91.33 ± 3.06	986.67 ± 120.55	70.25 ± 30.00	113.33 ± 15.28	96.67 ± 25.17	520.61 ± 70.00	48.33 ± 27.54	48.33 ± 27.54	45.02 ± 31.22
4	3	14.27 ± 0.92	101.06 ± 346	1,263.33 ± 63.51	103.34 ± 41.63	158.35 ± 40.10	131.67 ± 43.68	510.49 ± 135.28	40.37 ± 10.00	56.67 ± 37.86	33.33 ± 15.28
5	1	17.50	104.37			190.07	200.00				
6	2	19.40 ± 1.41	117.59 ± 0.71	1,270.82 ± 183.85	125.55 ± 77.78	210.36 ± 14.14	210.02 ± 14.14	700.83 ± 282.84	55.61 ± 35.36	65.06 ± 49.50	70.21 ± 56.57
7	3	26.57 ± 4.18	122.33 ± 2.52	1,196.91 ± 100.00	136.67 ± 63.51	230.42 ± 43.59	206.67 ± 11.55	873.33 ± 303.53	76.67 ± 32.15	76.67 ± 32.15	66.67 ± 11.55
8	0										
9	1	26.40	127.41	1,411.73	160.11	300.19	260.51	680.63	80.41	80.32	60.37
10	2	40.75 ± 5.16	141.16 ± 4.24	1,403.51	160.30 ± 56.57	285.20 ± 49.50	275.44 ± 36.36	760.72 ± 113.14	65.38 ± 35.36	70.04 ± 42.43	65.23 ± 35.36
11	4	45.63 ± 10.64	148.33 ± 6.77	1,262.53 ± 88.84	206.26 ± 138.13	298.33 ± 130.29	251.67 ± 55.29	1,208.83 ± 535.28	96.67 ± 38.82	90.14 ± 54.77	152.41 ± 69.07
12	1	51.64	152.20	1,260.28	200.41	300.57	300.29	1,400.77	100.52	120.28	80.08
13	3	49.48 ± 4.36	157.36 ± 6.93	1,245.03 ± 49.50	260.09 ± 56.57	256.67 ± 111.50	233.33 ± 98.66	865.09 ± 190.92	86.47 ± 55.08	80.09 ± 45.83	90.27 ± 42.43
14	6	48.73 ± 3.35	159.57 ± 3.27	1,303.33 ± 139.38	203.39 ± 8.16	388.31 ± 198.44	410.66 ± 155.82	953.33 ± 178.29	106.67 ± 8.16	105.14 ± 8.37	105.44 ± 34.50
15	4	54.24 ± 4.24	157.82 ± 5.36	1,285.19 ± 66.08	216.23 ± 16.73	296.28 ± 90.99	316.13 ± 79.25	1,296.39 ± 292.03	100.45 ± 14.14	100.21 ± 14.14	88.31 ± 17.89

The analysis of the mean body weight and height of both male and female subjects using the independent samples t-test revealed a statistically significant difference in mean height at the level of $p < 0.05$. Specifically, the average height of the male subjects was greater than that of the female subjects. Furthermore, with regard to the mean weights of internal organs, significant differences were observed for the mean weights of the heart, right lung, left lung, and spleen, also at the level of $p < 0.05$, with male subjects exhibiting higher mean organ weights compared to female subjects. These findings are presented in Table 3.

The results indicate that sex has a significant impact on the average body weight, height, and internal organ weights, with male deceases consistently surpassing female deceases in these measurements. These findings are consistent with the study conducted on cadavers within the Indian population by Vaibhav V et al. [6]

Table 3: The Correlation Between Body Weight, Height, and Internal Organ Weights in Male and Female Subject

Internal Organ	Mean		Independent Samples T-Test (p-value)
	Male	Female	
Brain	1,026.55	911.22	0.065
Heart	138.24	100.17	0.013*
Right Lung	223.39	161.76	0.011*
Left Lung	198.88	151.28	0.037*
Liver	681.54	549.62	0.068
Right Kidney	62.13	50.28	0.052
Left Kidney	63.02	50.95	0.055
Spleen	68.35	51.29	0.033*
Body Weight	26.46	20.81	0.063
Body Height	109.74	96.83	0.049*

* There is a statistically significant difference at the level of $p < 0.05$

From the analysis of the correlation between body weight and height with the weights of internal organs in male and female subjects aged 0–11 months using Pearson correlation, revealed significant findings. Both body weight and height had a statistically significant correlation at the level of $p < 0.001$ with the weights of the brain, heart, right lung, left lung, right kidney, and left kidney in the male subjects, as well as with the weights of the brain and liver in the female subjects. Furthermore, body weight and height demonstrated a statistically significant correlation at the level of $p < 0.05$ with the weight of the spleen in the male

subjects, and with the weights of the right lung, left lung, right kidney, left kidney, and spleen in the female subjects. It is noteworthy that the weight of the heart in the female sample did not exhibit a significant correlation with body weight and height. In the age group 1–15 years, both male and female subjects, it was observed that body weight and height demonstrated a statistically significant relationship with all internal organs at the level of $p < 0.001$. These findings are summarized in Table 3.

The results indicate that body weight and height are significantly correlated with internal organ weights, consistent with the study conducted on deceases from the South African population by Govender S et al.[7]

The data were analyzed using multiple linear regression, with the dependent variable defined as the mean weight of internal organs, and the independent variables comprising body weight, height, sex, and age. Table 4 presents the sample data for the age group of 0–11 months, while Table 5 provides the sample data for the age group of 1–15 years. This multiple linear regression analysis is consistent with research conducted on Thai deceases aged 15–89 years by Mathuramon P et al.[8]

Table 4: The Correlation Between Body Weight and Height with Internal Organ Weights of Male and Female Subjects in Age Groups (0-11 months and 1-15 years)

	Age 0-11 months			
	Body Weight		Body Height	
Internal Organ	Male (r)	Female (r)	Male (r)	Female (r)
Brain	0.856**	0.805**	0.898**	0.898**
Heart	0.639**	0.319	0.618**	0.282
Right lung	0.768**	0.558*	0.764**	0.552*
Left lung	0.712**	0.568*	0.752**	0.556*
Liver	0.832**	0.779**	0.828**	0.742**
Right kidney	0.516**	0.472*	0.670**	0.498*
Left kidney	0.562**	0.466*	0.848**	0.413*
Spleen	0.478*	0.458*	0.411*	0.368*

* There is a statistically significant difference at the level of $p < 0.05$

** There is a statistically significant difference at the level of $p < 0.001$

	Age 1-15 years			
	Body Weight		Body Height	
Internal Organ	Male (r)	Female (r)	Male (r)	Female (r)
Brain	0.669**	0.636**	0.717**	0.721**
Heart	0.823**	0.852**	0.792**	0.787**
Right lung	0.656**	0.734**	0.670**	0.736**
Left lung	0.682**	0.771**	0.708**	0.802**
Liver	0.763**	0.841**	0.713**	0.760**
Right kidney	0.709**	0.776**	0.696**	0.754**
Left kidney	0.731**	0.688**	0.699**	0.685**
Spleen	0.452**	0.691**	0.415**	0.659**

* There is a statistically significant difference at the level of $p < 0.05$

** There is a statistically significant difference at the level of $p < 0.001$

Table 5: Summary of the Multiple Linear Regression Equation Relating Internal Organ Weight to Body Weight, Sex, and Age in the Sample Aged 0–11 Months

Organ	Body Weight $Y = a + bx_1 + cx_2 + dx_3$	R^2
Brain	Brain Weight = 228.610 + 51.27(Body Weight) + 15.17(Sex) + 22.42(Age)	0.79
Heart	Heart Weight = 13.10 + 2.97(Body Weight) + 2.20(Sex) + 0.42(Age)	0.28
Lungs	Total Lungs Weight = 23.83 + 13.44(Body Weight) + 7.10(Sex) + 2.38(Age)	0.51
Liver	Liver Weight = 51.86 + 24.75(Body Weight) + 18.97(Sex) + 3.65(Age)	0.68
Kidneys	Total Kidneys Weight = 17.40 + 2.59(Body Height) + 4.41(Sex) + 2.55(Age)	0.35
Spleen	Spleen Weight = 0.04 + 3.44(Body Weight) + 6.03(Sex) + 0.16(Age)	0.23
Brain	Brain Weight = -555.235 + 19.15(Body Height) + 2.26(Sex) + 4.73(Age)	0.81
Heart	Heart Weight = -21.60 + 0.90(Body Height) + 1.64(Sex) - 0.10(Age)	0.25
Lungs	Total Lungs Weight = -179.64 + 4.96(Body Height) + 4.46(Sex) - 2.09(Age)	0.51
Liver	Liver Weight = -275.35 + 8.25(Body Height) + 13.14(Sex) - 2.95(Age)	0.64
Kidneys	Total Kidneys Weight = -27.75 + 0.96(Body Height) + 3.72(Sex) + 1.66(Age)	0.35
Spleen	Spleen Weight = -28.73 + 0.82(Body Height) + 5.46(Sex) - 0.06(Age)	0.17

Unit: internal organ weight = gram, body weight = kilogram, age = month

Table 6: Summary of the Multiple Linear Regression Equation Relating Internal Organ Weight to Body Height, Sex, and Age in the Sample Aged 1-15 Years

Organ	Body Weight	
	$Y = a + bx_1 + cx_2 + dx_3$	R^2
Brain	Brain Weight = 936.531 + 3.582(Body Weight) + 100.43(Sex) + 15.08 (Age)	0.50
Heart	Heart Weight = 21.74 + 2.73(Body Weight) + 17.96(Sex) + 5.14(Age)	0.71
Lungs	Total Lungs Weight = 104.95 + 2.38(Body Weight) + 56.92(Sex) + 33.31(Age)	0.55
Liver	Liver Weight = 234.94 + 16.18(Body Weight) + 43.07(Sex) + 8.17(Age)	0.63
Kidneys	Total Kidneys Weight = 50.43 + 1.90(Body Weight) + 8.01(Sex) + 4.07(Age)	0.56
Spleen	Spleen Weight = 31.50 + 1.01(Body Weight) + 13.06(Sex) + 1.60(Age)	0.31
Brain	Brain Weight = 140.91 + 1.986(Body Height) + 30.449(Sex) - 50.58(Age)	0.62
Heart	Heart Weight = 44.86 - 0.19(Body Height) + 20.40(Sex) + 15.69(Age)	0.68
Lungs	Total Lungs Weight = -50.87 + 2.32(Body Height) + 49.25(Sex) + 26.62(Age)	0.55
Liver	Liver Weight = 376.84 - 1.17(Body Height) + 50.48(Sex) + 71.15(Age)	0.58
Kidneys	Total Kidneys Weight = 24.24 + 0.46(Body Height) + 7.44(Sex) + 7.62(Age)	0.54
Spleen	Spleen Weight = 48.02 - 0.18(Body Height) + 13.90(Sex) + 6.17(Age)	0.29

Unit: internal organ weight = gram, body weight = kilogram, age = year

Discussion

This study analyzed data from the autopsy records of Thai children under the age of 16, sourced from the Institute of Forensic Medicine at the Police General Hospital, the largest single center for autopsy. Each case underwent an autopsy performed by forensic medicines following established standards, which included both gross examination and microscopic analysis to identify pathological conditions and causes of death for critical internal organs, including the brain, heart, lungs, liver, kidneys, and spleen. The results regarding body weight, height, and internal organ weights were detailed for each age group, specifically 0–11 months and 1–15 years, to provide comprehensive data on Thai pediatric deceases.

However, several limitations were identified within the subjects, which does not encompass all age ranges. Notably, there is a lack of data for male and female subjects at 6 months of age, female subjects at 8 months, male and female subjects at 11 months, male and female subjects at 8 years, and male subjects at 10 years. This limitation was solved by the application of multiple linear regression equations for estimating internal organ weights

based on the height or weight of deceases, along with sex and age, for cases not represented in the database.

Additionally, there is another limitation regarding data recording within the database, which restricts access to certain information prior to the year 2020. This restriction hinders the ability to include earlier data in the analysis, resulting in a sample size for this study that remains smaller than ideal.

Conclusions

The results of this study provide detailed insights into the mean body weight, height, and internal organ weights of Thai children under the age of 16, categorized by sex and specific age groups of 0–11 months and 1–15 years. This information serves as a valuable reference for the normal weight of internal organs, including the brain, heart, lungs, liver, kidneys, and spleen, in the context of autopsies performed on Thai pediatric deceases.

Utilizing autopsy data from other ethnic groups as a reference can lead to inaccuracies, as ethnicity influences both body size and the weight of internal organs. Furthermore, data from adult cadaver samples cannot be used for reference, as the growth rates and physiological characteristics of children differ significantly from those of adults, which can also contribute to discrepancies in findings.

Acknowledgments

Author would like to extend my sincere gratitude to Natthapong Kittisoponpun M.D., forensic medicine at the Institute of Forensic Medicine, Police General Hospital

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ORIGINAL ARTICLE

Concordance and economic evaluation of postmortem CT for determining cause of death in traffic injuries and falls from heights

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Conflict of interest: The authors declare that they have no conflicts of interest with the contents of this article.

Submitted: *21 April 2025*
Accepted: *2 June 2025*
Published: *1 June 2026*

Abstract

Introduction: Postmortem CT (PMCT) is widely used in forensic investigations. This approach requires minimal intervention with the body, less time-consuming, offering high sensitivity detecting fractures, injuries, and air. PMCT has limitations in assessing soft tissues and solid organs. Financial factors, such as scanner costs and training, should also be considered.

Objective: To evaluate the concordance and cost-effectiveness analysis comparison between PMCT versus PMCT with autopsy and histological examination for determining the cause of death in traffic injuries and falls from heights.

Research method: This research is a retrospective study. The samples are bodies that died from traffic injuries and falls from heights which underwent PMCT with autopsy and histological examination at the Department of Forensic Medicine, Chulalongkorn University, Thailand, over 2023. The researchers determined the cause of death by PMCT results and compared it with the cause of death from autopsy reports.

Results: The cause of death determined by PMCT was concordance with the autopsy findings in 154 of 173 cases (89.02%). Discordance due to (1) Limitations of PMCT in 6 cases (3.47%) which PMCT failed to detect brainstem, spinal cord injury, and cardiac injury (2) Expert opinion in determining the cause of death in 10 cases (5.78%), (3) PMCT specific finding (tension pneumothorax) in 3 cases (1.73%). The cost of PMCT and autopsy combined with histology examination is 12,200 THB per case. The cost of PMCT is 4,094 THB per case. Effectiveness in determining the cause of death, in concordance with the autopsy findings, is 89.02%. PMCT combined with autopsy and histology costs 738.25 THB for each 1% gain in effectiveness compared to PMCT alone.

Conclusion: PMCT can determine the cause of death in most cases, matching the results of autopsy, and is more cost-effective. It may be a suitable guide for application in some situations to reduce future costs.

Keywords: Postmortem computed tomography (PMCT), Autopsy, Trauma, Cause of death, Economic evaluation.

Introduction

Postmortem imaging has been integrated into forensic investigations worldwide, including in Thailand. This approach requires minimal intervention with the body which aligns with some cultural beliefs and religious practices. It is less time-consuming and reduces the risk of disease transmission to personnel. Additionally, it produces digital record which is conveniently stored, accessed, and utilized for research, consultation, or legal proceedings in court [(1)].

Radiological imaging serves an important role in autopsy by identifying areas of interest and facilitating the identification of the deceased. It improves the evaluation of fractures and their patterns which could be time-consuming to assess by standard autopsy which are valuable in court. Additionally, it identifies radiopaque objects such as bullets and effectively assessing air or blood in the thoracic or abdominal cavity. However, it does have limitations, particularly in assessing soft tissue injuries and evaluating the muscle, brainstem, spinal cord, heart, blood vessels, and abdominal organs. Moreover, there are financial factors to consider, including the initial costs of equipment such as CT scanners, materials, and user training [(1-9)].

According to guidelines for post-mortem radiological imaging, a review of the history, death circumstance, and external examination of the body, combined with postmortem CT (PMCT), can determine the cause of death in cases involving blunt force trauma, such as traffic injuries or falls from height, provided the case is not under litigation or criminal investigation. [(10-11)]

PMCT has lower cost than standard autopsy [(3, 12-15)]. Therefore, the researchers aim to evaluate the concordance and cost-effectiveness analysis comparison between PMCT versus

PMCT with autopsy and histological examination for determining the cause of death in traffic injuries and falls from heights [12, 16-17].

Materials and Methods

Case Selection

The deceases from traffic injuries and falls from heights, underwent examination at the Department of Forensic Medicine, Chulalongkorn University, Thailand, over 1 year from 1st January 2023 to 31st December 2023. Based on these criteria, the following bodies are excluded: (1) Bodies that were not autopsied. (2) Bodies with incomplete PMCT data or autopsy information. (3) Bodies whose PMCT images were heavily affected by metallic artifacts which complicate the identification of details and determination of cause of death. The total number of cases in this study is 173 cases. These included 126 cases of traffic injuries and 47 cases of falls from heights.

The study has been reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Chulalongkorn University, and received an exemption from ethics consideration with Institutional Review Board (IRB) number 0791/67 and Certificate of Exemption number 071/2024.

CT-measurement

A non-contrast PMCT was conducted with a GE Revolution EVO CT scanner, The scanning conditions were 128 slices, 120 kV tube voltage, 200 mA tube current, and 0.8 s rotation time, visualized by a GE Healthcare media viewer.

Method

The standard practice at the Department of Forensic Medicine, Chulalongkorn University, Thailand, is to perform PMCT followed by an autopsy and histological examination in every case to determine the official cause of death.

Two researchers, blinded and independent, reviewed the PMCT results of the selected cases without access to information about the history from scene investigation, treatment history, external examination findings, or autopsy results. Each investigator documented significant findings from the PMCT and determined the cause of death based on the most severe injury and the fastest fatal mechanism. In cases where multiple severe injuries are identified in adjacent areas, the cause of death will be documented as multiple organ injuries, with a detailed specification of each site of injury included [18]., Following this, the concordance rate of the cause of death from the results of the PMCT with the findings in the autopsy report will be evaluated.

In cases of discordance, cases are categorized into three groups: (1) Discordance due to limitations of PMCT, which refers to cases in which the PMCT cannot identify injuries that

may be the cause of death, such as the brainstem and spinal cord injuries or cardiac injuries, (2) Discordance due to expert opinion in determining the cause of death, which refers to cases in which the PMCT results identifies injuries that align with the autopsy findings, but the cause of death is interpreted differently by the experts involved, (3) Discordance due to CT specific finding such as tension pneumothorax, which is an acutely life-threatening condition, and detectable through a PMCT.

Analyze the costs associated with performing an autopsy compared to PMCT. This analysis will be divided into three categories: labor costs (including salaries), material costs (including consumables, water, and electricity), and capital costs (including equipment, machinery, tools, and buildings). Following this, a cost-effectiveness analysis of PMCT compared to PMCT and autopsy combined with histology will be conducted.

Results

Demographic Data

The bodies that died from traffic injuries and falls from heights, 192 cases were recorded, 173 cases underwent PMCT and autopsy ,with complete PMCT and autopsy data, while 19 cases that did not perform autopsy because (1) The cause of death can be determined from the post-mortem CT result 8 cases, (2) The family has requested that no autopsy be performed, along with the medical record data 4 cases. (3) Religious objections to post-mortem dissection 6 cases (4) reduce the risk of infectious diseases 1 case. The cause of death from autopsy report is shown in Table 1.

126 cases of traffic injuries were recorded, consisting of 100 males (79.37%) and 26 females (20.63%). The mean age (sd) was 36.63 (±17.26) years.

47 cases of falls from heights were recorded, consisting of 40 males (85.11%) and 7 females (14.89%), The mean age (sd) was 39.7 (±18.46) years.

In total, 173 cases of traffic injuries and falls from heights were recorded, consisting of 140 males (80.92%) and 33 females (19.08%), The mean age (sd) was 37.48 (±17.59) years.

Table 1: Cause of death from autopsy report. (PMCT with autopsy and histological examination)

Cause of death	Traffic injury	Falls from heights	Total
Head injury	62 (49.21%)	17 (36.14%)	79 (45.66%)
Brainstem or spinal cord injury	8 (6.35%)	4 (8.51%)	12 (6.94%)
Thoracic organ injury	21 (16.67%)	6 (12.77 %)	27 (15.61%)
Abdominal organ injury	3 (2.38%)	1 (2.13%)	4 (2.31%)
Multiple organ injury	25 (19.84%)	18 (38.3%)	43 (24.86%)
- Head and brainstem or spinal cord	2 (1.59%)	1 (2.13%)	3 (1.73%)
- Head and thoracic organ	4 (3.17%)	1 (2.13%)	5 (2.89%)
- Head and abdominal organ	1 (0.79%)	0 (0%)	1 (0.58%)
- Head and thoracic and abdominal organ	7 (5.56%)	4 (8.51%)	11 (6.36%)
- Head and brainstem or spinal cord and thoracic and abdominal organ	0 (0%)	2 (4.26%)	2 (1.16%)
- Brainstem or spinal cord and thoracic organ	1 (0.79%)	1 (2.13%)	2 (1.16%)
- Thoracic and abdominal organ	10 (7.94%)	9 (19.15%)	19 (10.98%)
Other			
- Multiple bone fracture	3 (2.38%)	1 (2.13%)	4 (2.31%)
- Complication from injury	3 (2.38%)	0 (0%)	3 (1.73%)
- Nontraumatic basal ganglia hemorrhage	1 (0.79%)	0 (0%)	1 (0.58%)
Total	**126**	**47**	**173**

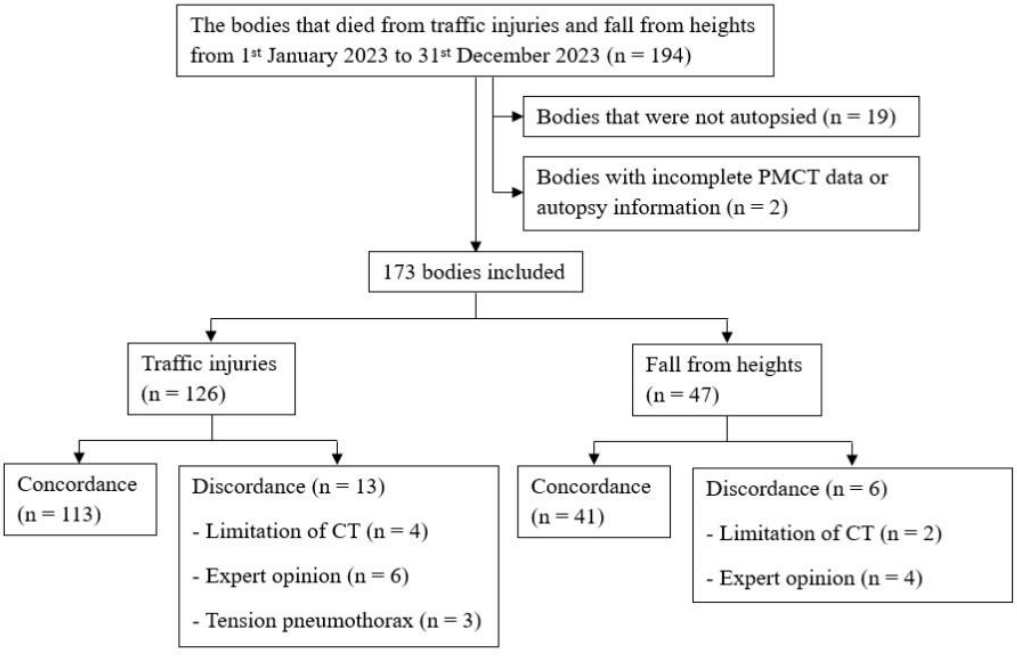

Figure 1: Flowchart describing the number of cases in each group and concordance rate.

Concordance rate of the Cause of Death Identified by PMCT Compared to Autopsy Findings

For the deceases from traffic injuries, 126 cases underwent autopsy. The cause of death identified by PMCT was concordance with the autopsy findings in 113 cases (89.68%). In cases of discordance, the reasons were as follows: discordance due to limitations of PMCT in 4 cases (3.18%), discordance due to expert opinion in determining the cause of death in 6 cases (4.76%), discordance due to PMCT specific finding (tension pneumothorax) in 3 cases (2.38%)

For the deceases that died from falls from heights, 47 cases underwent autopsy. The cause of death identified by PMCT was concordance with the autopsy findings in 41 cases (87.23%). In cases of discordance, the reasons were as follows: discordance due to limitations of PMCT in 2 cases (4.26%), discordance due to expert opinion in determining the cause of death in 4 cases (8.51%)

In total, of the bodies that died from traffic injuries and falls from heights, 173 cases underwent autopsy. The cause of death identified by PMCT was concordance with the autopsy findings in 154 cases (89.02%). In cases of discordance, the reasons were as follows: discordance due to limitations of PMCT in 6 cases (3.47%), where the PMCT failed to detect brainstem and spinal cord injury in 5 cases, and cardiac injury in 1 case., discordance due to expert opinion in determining the cause of death in 10 cases (5.78%), discordance due to PMCT specific finding (tension pneumothorax) in 3 cases (1.73%). The causes of death in discordance cases is shown in Table 2.

In this study, there were 20 cases of brainstem and spinal cord injuries, PMCT can detect the injury in 15 cases (75%) and failed to detect 5 cases (25%). There were 17 cases of heart injury, PMCT can detect the injury in 12 cases (70.59%) and failed to detect 5 cases (29.41%). Among these, 4 cases showed hemopericardium, PMCT cause of death are suspected due to heart or vascular injury, while 1 case showed no abnormalities.

Table 2: Causes of death in discordance cases.

	Autopsy	Post-mortem CT
Due to the limitations of PMCT		
Traffic injuries	Brainstem laceration	Brain contusion with subarachnoid hemorrhage
	Brainstem laceration	Subarachnoid hemorrhage with skull fracture
	Brain laceration with cardiac contusion	Brain laceration
	Brainstem laceration with aortic injury	Aortic injury
Falls from heights	Cervical spinal cord laceration	Lung contusion with hemopneumothorax
	Brain and brainstem laceration	Brain contusion with subarachnoid hemorrhage
Due to expert opinion in determining the cause of death		
Traffic injuries	Lung laceration due to ribs fracture	Subarachnoid hemorrhage with lung laceration and pneumothorax
	Subarachnoid hemorrhage with lung contusion with spleen contusion	Lung contusion with hemothorax
	Subarachnoid hemorrhage	Subarachnoid hemorrhage with lung contusion
	Subdural with subarachnoid hemorrhage	Subarachnoid hemorrhage and hallow viscus organ perforation with hemopneuomoperitoneum
	Brain laceration	Brain and lung laceration
	Brain contusion with subarachnoid hemorrhage	Subarachnoid hemorrhage with hemopneumothorax
Falls from heights	Multiple bone fractures with colon cancer	Thoracic and abdominal organ injury
	Subarachnoid hemorrhage	Lung contusion with subarachnoid hemorrhage
	Subarachnoid hemorrhage with lung contusion with hilar of liver, spleen, and kidney contusion	Brain contusion with subarachnoid hemorrhage
	Subarachnoid hemorrhage	Subarachnoid hemorrhage with lung contusion
Due to PMCT specific finding (tension pneumothorax)		
Traffic injuries	Brain laceration	Tension pneumothorax
	Subarachnoid hemorrhage with aortic injury with lung, liver, and spleen laceration	Tension pneumothorax
	Brain contusion with lung contusion	Tension pneumothorax

Economic evaluation of PMCT versus autopsy

Cost

According to the Data management and cost evaluating center, King Chulalongkorn Memorial Hospital: The Thai Red Cross Society

The cost of autopsy (4,713 THB per case) is divided into Labor costs: including doctors (not include professional fees), autopsy assistants, photographers, and administrative staff, Material costs: including autopsy instruments, water, and electricity, Capital costs: including computer, printer, corpse and organ weighing scales, surgical bed, electric saw, camera, and building costs.

The cost of histology examination (3,393 THB per case) is divided into Labor costs: including doctors, and medical scientists, Material costs: including formalin for tissue preparation, H&E (Hematoxylin & Eosin) staining equipment, water, and electricity, Capital costs: including tissue cutting table, tissue cutting and H&E staining machines, image scanning machine, sample storage cabinet, chemical balance, biosafety cabinet, computer, and building costs.

The cost of PMCT (4,094 THB per case) is divided into Labor costs: including doctors (not include professional fees), staff, and general service staff, Material costs: including gloves, and electricity, Capital costs: including computer, CT scanner, and building costs

In summary, the cost of PMCT is 4,094 THB per case, the Cost of Autopsy combined with histological examination is 8,106 THB per case, Actual cost at the Department of Forensic Medicine, Chulalongkorn University for PMCT and autopsy combined with histology is 12,200 THB per case

Cost-effectiveness analysis

The cost of PMCT and autopsy combined with histology examination is 12,200 THB per case. Effectiveness in determining cause of death is 100%.

The cost of PMCT is 4,094 THB per case. Effectiveness in determining the cause of death, in concordance with the autopsy findings, is 89.02%.

When comparing PMCT to PMCT combined with autopsy and histology, PMCT is 8,106 THB cheaper with 10.98% less effective. The Incremental Cost-Effectiveness Ratio (ICER) is calculated by dividing the difference in costs by the difference in effectiveness, resulting in 738.25 THB per 1% increase in effectiveness. This indicates that PMCT combined with autopsy and histology costs 738.25 THB for each 1% gain in effectiveness compared to PMCT alone.

The cost actually incurred in the year 2023 for: (1) PMCT and autopsy combined with forensic histology (173 cases) was 2,110,600 THB (2) PMCT without autopsy and forensic pathology examination (19 cases) 77,786 THB

In 2023, there were cost savings of 154,014 THB (6.57%), compared to conducting PMCT and autopsy combined with forensic histology on all cases (192 cases, with a cost of 2,342,400 THB).

If the accurate cause of death can be determined using a PMCT then not performing an autopsy and histology, the cost will be: (1) PMCT and autopsy combined with forensic histology (19 cases) 231,800 THB (2) PMCT without autopsy and forensic pathology examination (154 cases) 630,476 THB.

There will be cost savings of 1,248,324 THB per year (59.15%), compared to conducting PMCT and autopsy combined with forensic histology on all cases (173 cases, with a cost of 2,110,600 THB).

Discussion

The concordance rate of the cause of death from PMCT with autopsy in traumatic death, From Schmitt-Sody et.al [19] study is 16/17 patients (94.1 %). In the cases of discordant, the CT scan did not detect fatal injuries, while the autopsy reported chest compression with most likely suffocation. Willaume et.al. [20] can determine the cause of death from PMCT in all 40 cases. K. et.al. [21] found that the concordance rate is 9/10 cases (90%). In the cases of discordance, the PMCT indicated death due to complications from a head injury, while the autopsy identified death due to complications from a chest injury. Mishra et.al. [22] studied the determination of cause of death using post-mortem CT scans compared with autopsy. They found concordance in the following causes of death: hemorrhagic shock in 4 out of 12 cases (33%), head injuries in 14 out of 21 cases (67%), injuries to the heart and lungs in 6 out of 8 cases (75%), and multiple injuries in 2 out of 3 cases (67%)

In this study, due to the larger number of cases, the cases are categorized and discussed into three groups.

Discordance due to limitations of PMCT, 6 cases (3.47%), PMCT result failed to detect brainstem and spinal cord injuries in 5 cases and cardiac contusion in 1 case. Normally, injuries to the brainstem, spinal cord, and heart are difficult to visible on non-contrast PMCT [4, 5, 23]. In this study, PMCT can detect the injury when there is air present at the laceration site or the laceration is separated or distorted, with bone displacement or fractures that penetrate the tissue of the affected organs.

Discordance due to expert opinion in determining the cause of death, there were 10 cases (5.78%) where injuries to organs were detected through both PMCT and autopsy, but the opinions on the cause of death differed. The differences in interpretation between researchers and pathologists can be attributed to their varying experiences and the information available to them. Pathologists have access to the history from scene investigation, treatment history, external examination findings, and the results from the PMCT before they conduct the autopsy and establish the cause of death. In contrast, researchers depend exclusively on the

PMCT for their assessments, as they do not have access to essential background information that could aid in determining the cause of death.

Discordance due to PMCT specific finding (tension pneumothorax) in 3 cases (1.73%), this condition is life-threatening and can be fatal if not treated promptly. Generally, CT scans are more sensitive in identifying pneumothorax compared to conventional autopsy [3, 7-8]. The detection of pneumothorax during an autopsy can be performed by opening the thoracic cavity underwater and observing for the presence of air bubbles. But tension pneumothorax was defined as the presence of an opposite mediastinal shift with hemodynamic compromise. It is a clinical diagnosis and can progress by positive pressure ventilation [24]. Discordance may be because of expert opinion and pathologists have all the information including treatment history to determine the cause of death.

In Thailand, the availability of forensic pathologists remains limited, with some provinces lacking this specialist. As a result, it is often necessary to transport bodies to other provinces for autopsy services, while every province has a CT. From Waldhoer et.al. study [25], Autopsy rates decrease as the distance from the place of death to the nearest autopsy facility increases, and believe that the impact of distance may be partly influenced by financial considerations related to the administration of autopsies.

The results of this study suggest that PMCT has a lower cost than performing an autopsy. The cost of PMCT is 4,094 THB per case, with 89.02% effectiveness. PMCT may be an alternative option in some settings, such as when the manner of death is clearly known from the examination at the scene. PMCT may be utilized alongside consultations with a forensic pathologist, rather than transporting bodies across provinces for autopsies

There are several limitations to this study. It is a retrospective study based on usual practice, so the pathologist is not blinded to the PMCT results, which may influence the determination of the cause of death, and histological examination is performed in every case. Therefore, this study cannot analyze the effectiveness and cost-effectiveness analysis of autopsy alone (without PMCT and histological examination, which may be practiced in other centers) compared to PMCT alone. Due to the limitations of non-contrast PMCT in assessing soft tissue injuries, brainstem, spinal cord, heart, blood vessels, and solid organs, the cause of death from PMCT results may not be able to precisely identify the specific solid organ or vessel injured in some cases. However, it can detect relative findings such as massive hemopericardium, hemothorax, or hemoperitoneum and determine the cause of death based on the most severe injury region.

Conclusion

PMCT can determine the cause of death in traffic injuries and falls from heights, with 154 out of 173 cases (89.02%) matching autopsy results. There are limitations in detecting injuries to the brainstem, spinal cord, and heart. CT scans are more effective than traditional autopsy techniques in identifying pneumothorax. Reviewing post-mortem CT results combined with information from scene investigations, treatment history, external examination findings, and autopsy results may enhance the accuracy of determining the cause of death.

PMCT has a lower cost than performing an autopsy. The cost of PMCT is 4,094 THB per case, with 89.02% effectiveness. PMCT combined with autopsy and histology costs approximately 738 THB for each 1% gain in effectiveness compared to PMCT alone. This study may serve as a guide for considering forensic practices to reduce future costs. It presents a potential strategy for areas that do not have a forensic pathologist.

This study focuses on traffic injuries and falls from height. Future research may be conducted on deaths from other causes, including cases involving individuals with a history of infectious diseases, which may pose an infection risk during autopsy, bodies where CT scans identify a clear cause of death, such as hypertensive intracerebral hemorrhage, and other natural cause of death. The economic evaluation in this study focuses solely on PMCT and autopsy with histology examination. Future research may study about the concordance rate of the autopsy with and without histology examination in traumatic cases, or cover the costs of cadaver transport.

Acknowledgments

The researchers would like to thank the biostatistician for their guidance. I acknowledge using ChatGPT and Grammarly for translation and grammar checking.

Conflicts of Interest

The researchers declare that they have no conflicts of interest with the contents of this article.

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ORIGINAL ARTICLE

Sudden Unexpected Death Due To Central Nervous System Pathology

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Conflict of interest: The authors declare that they have no conflicts of interest with the contents of this article.

Submitted: *9 March 2025*
Accepted: *28 April 2025*
Published: *1 June 2026*

Abstract

Background: Sudden unexpected death due to central nervous system (CNS) pathology is among the leading causes of sudden death. Understanding the nature of sudden neurologic deaths is crucial in forensic medicine practice. This data can be used to enhance the accuracy of the cause and manner of death determination.

Material and method: This study was a retrospective autopsy report review at the Faculty of Medicine Siriraj Hospital in Bangkok, Thailand.

Result: During 2019 – 2023, 222 autopsy cases were identified as sudden neurologic deaths. The majority of cases are males (77.0%) and the mean age is 49 years old (age range 22-87). The most common cause is intracerebral hemorrhage (n=87, 39.2%), followed by brainstem hemorrhage (n=60, 27.0%), and subarachnoid hemorrhage (n=49, 22.0%). Other causes include cerebellar hemorrhage (n=6, 2.7%), cerebral infarction (n=6, 2.7%), brain tumor (n=5, 2.3%), infection (n=4, 1.8%), spontaneous subdual hemorrhage (n=3, 1.3%), spontaneous intraventricular hemorrhage (n = 1, 0.5%), and sudden unexpected death in epilepsy (SUDEP; n=1, 0.5%). Positive toxicology tests (ethanol and methamphetamine) tend to be present in cases with intracranial hemorrhage.

Conclusion: Intracerebral hemorrhage was the most common cause of sudden neurologic death in forensic autopsy population. In contrast to previous study, SUDEP is rarely diagnosis in this population.

Keywords: Central nervous system, Forensic autopsy, Sudden neurological death, Sudden unexpected death

Introduction

Sudden death is defined as an unexpected death that occurs rapidly following an abnormal event, where the physician is unable to ascertain a clear cause of death [(1)]. The World Health Organization describes sudden death as natural death occurring within 24 hours after the onset of symptoms [(1)].

The incidence of sudden neurologic death ranks second only to sudden cardiac death [(2)]. In the literature, epilepsy has been reported as the most common cause of sudden neurological death [(2)]. The prevalence of sudden unexpected death in epilepsy (SUDEP) varies among different populations, ranging from 0.4 to 1.35 per 1,000 person-years [(2)]. In a study from the UK, it was reported as high as 4.9 per 1,000 person-years [(3)].

Sudden neurologic death holds considerable importance in forensic medicine practice, as forensic physicians/pathologists are often requested to identify the exact cause and manner of death (whether natural, accidental, homicidal, or suicidal) as a part of death investigation. Portray of vital data in this field should enable forensic practitioner to be more accurate in determining the specific causes of death.

Currently, information regarding sudden death in Southeast Asian populations is still limited. Gathering data on deaths arising from central nervous system pathologies, along with contributing factors, will also serve as a crucial database for the further investigation of sudden death in general.

Materials and Methods

Study design

Forensic autopsy reports at the Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital were reviewed in a cross-sectional retrospective study. Data collection commenced following an approval from the Institutional Review Board of the Faculty of Medicine, Siriraj Hospital (Approval Number Si 955/2023).

The reports from January 2019 to December 2023 were examined for individuals older than one year-old with sudden death related to neurological causes. The autopsy data were later extracted for analysis. These collected data include age, weight, height, underlying medical conditions, gross autopsy findings, brain weight and pathology, microscopic findings, and toxicological test results. Cases with external examination only and those with advance decomposition changes were excluded from the analysis.

Statistical Analysis

Statistical analysis was conducted utilizing IBM SPSS Statistics software version 26. An unpaired t-test was employed to compare continuous variables, while the chi-square test was used for comparing categorical variables. One-way ANOVA was applied to assess differences between groups. A p-value of less than 0.05 was considered statistical significance.

Results

A total of 9,547 forensic autopsy cases were conducted in our institution over the 5-year period (2019 – 2023). Among these, 222 cases were identified as sudden neurologic deaths. The majority of cases are males (77.0%). The mean age is 49. The incidents are distributed across three age groups: individuals aged over 50 years (n = 106; mean age = 60), followed by those aged 36–50 years (n = 99; mean age = 44), and finally, individuals aged 19–35 years (n = 17; mean age = 30).

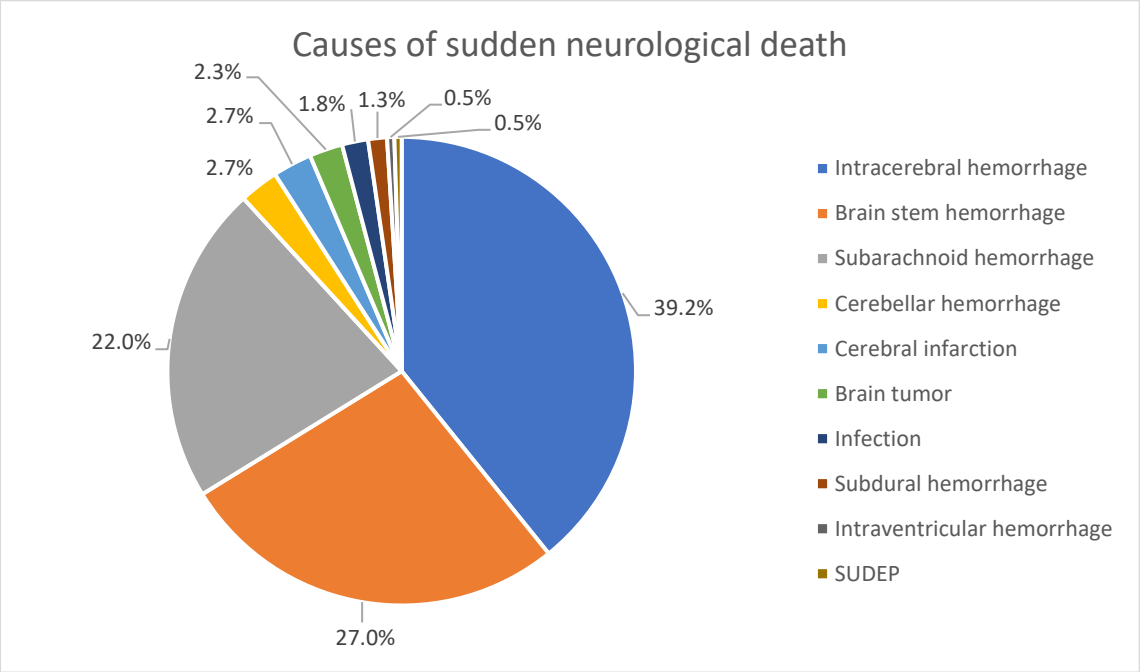

Figure 1: Causes of sudden neurologic death

The causes of death are portrayed in figure 1. The leading cause of sudden neurologic death was intracerebral hemorrhage (basal ganglion and thalamic hemorrhages; n = 87, 39.2%), followed by brainstem hemorrhage (n = 60, 27.0%) and spontaneous subarachnoid hemorrhage (n = 49, 22.0%). Other causes include cerebellar hemorrhage (n = 6, 2.7%), cerebral infarction (n = 6, 2.7%), brain tumor (n = 5, 2.3%), infection (n = 4, 1.8%), spontaneous subdual hemorrhage (n = 3, 1.3%), spontaneous intraventricular hemorrhage (n = 1, 0.5%) and SUDEP (n = 1, 0.5%). The demographic data for each etiology is shown in Table 1-2.

Table 1: Characteristic data for each group

Cause of Death	Number, %	Age (mean ± SD)	Gender (M:F)	BMI (mean ± SD)	Brain Weight (mean ± SD)
Intracerebral hemorrhage	87, 39.2%	51.2 ± 10.7	9:2	22.7 ± 4.6	1,368.8 ± 122.8
Brainstem hemorrhage	60, 27.0%	50.1 ± 10.0	9:1	24.6 ± 4.4	1,318.9 ± 17.3
Cerebellar hemorrhage	6, 2.7%	52.8 ± 13.9	2:1	23.3 ± 6.2	1,351.3 ± 60.8
Subarachnoid hemorrhage	49, 22.0%	49.2 ± 12.4	3:2	24.4 ± 4.9	1,340 ± 129.2
Other					
- Cerebral infarction	6, 2.7%	50.0 ± 10.5	2:1	24.1 ± 4.9	1,348 ± 140.5
- Brain tumor	5, 2.3%	49.5 ± 10.9	1:4	24.0 ± 4.8	1,347 ± 132.9
- Infection	4, 1.8%	50.6 ± 10.8	1:0	23.7 ± 4.8	1,357 ± 139.7
-Subdural hemorrhage	3, 1.3%	51.3 ± 11.1	2:1	23.4 ± 4.6	1,350 ± 142.5
-Intraventricular hemorrhage	1, 0.5%	37	1:0	27.0	1,510
- SUDEP	1, 0.5%	62	1:0	21.5	1,000

One case of SUDEP found in this study was a 62-year-old man with an underlying disease of epilepsy. Prior to his death, the individual was observed experiencing a seizure episode. Antiepileptic medication was found among his personal belongings. An autopsy revealed an old infarct in the basal ganglia but no other significant pathological findings. The cause of death was rendered as SUDEP.

One case of spontaneous intraventricular hemorrhage involved a 37-year-old male with no known medical condition. He was found deceased in his sleep. Internal examination revealed significant brain swelling and a 60-gram intraventricular blood clot, with no other brain lesion present. The cause of death was determined to be intraventricular hemorrhage.

There were 30 cases with positive toxicology results, which were categorized into three groups for this study. The first group consisted of stimulant drugs, all of which were methamphetamine and amphetamine, and were detected in 15 cases. The second group was alcohol, which was present in 14 cases. The final group was opioid, with only one case identified. The group with the highest incidence of substance use was those who died from brainstem hemorrhage, with 14 cases (alcohol = 7, stimulants = 7). This was followed by the intracerebral hemorrhage group, with 7 cases (alcohol = 3, stimulants = 4), and the subarachnoid hemorrhage group, with 6 cases (alcohol = 2, stimulants = 4). These results are shown in Table 3

Table 2: Age distribution for each group

	Age Group			
Cause of Death	**1-18**	**19-35**	**36-50**	**>50**
Intracerebral hemorrhage	-	6	33	48
Brainstem hemorrhage	-	3	31	26
Cerebellar hemorrhage	-	-	3	3
Subarachnoid hemorrhage	-	4	26	19
Other				
- Cerebral infarction	-	1	1	4
- Brain tumor	-	2	1	2
- Infection	-	1	2	1
- Subdural hemorrhage	-	-	1	2
- Intraventricular hemorrhage	-	-	1	-
- SUDEP	-	-	-	1

Table 3: Toxicological report for hemorrhage group

	Toxicology Result		
Cause of Death	**Alcohol**	**Stimulant**	**Opioid**
Intracerebral hemorrhage	3	4	-
Brainstem hemorrhage	7	7	-
Cerebellar hemorrhage	1	-	-
Subarachnoid hemorrhage	2	4	-
Total	**13**	**15**	**0**

Discussion

In this study, intracranial hemorrhage was much more common in male compared to female. This finding aligns with previous studies conducted in both Asian populations and other demographic groups that male is more susceptible to intracranial hemorrhage at all age group [4-6]. Men are more susceptible to hemorrhage due to risk factors such as smoking and alcohol consumption [5-7].

Sudden death due to intracranial hemorrhage, including intracerebral hemorrhage, brainstem hemorrhage and cerebellar hemorrhage, was the most prevalent finding in this study, comprising 40.1%, 25.2% and 3.6% of cases, respectively. Intracerebral

hemorrhage identified in this study were primarily located in the basal ganglion and thalamus. This finding contrasts with previous research, which reported that SUDEP is more commonly observed in cases of sudden neurologic death [(1)].

The primary causes of spontaneous intracerebral hemorrhage are arteriolosclerosis and cerebral amyloid angiopathy (CAA). Arteriolosclerosis is characterized by abnormal thickening of the walls of arterioles that supply the basal ganglia, thalamus, brainstem, and deep cerebellar nuclei. Major risk factors for this condition include male sex, hypertension, diabetes mellitus, advanced age and alcohol consumption [(7-8)].

Spontaneous subarachnoid hemorrhage in this study was primarily caused by ruptured cerebral aneurysms and ruptured arteriovenous malformations, respectively. This condition accounted for 22.1% of all cases, making it the third most common cause of sudden neurologic death in this study. Risk factors for non-traumatic subarachnoid hemorrhage include hypertension, smoking, alcohol consumption, the use of sympathomimetic drugs, and female sex [(9)]. Rupture aneurysm is presented in 73.5% of cases and only one case of arteriovenous malformations (AVMs).

Intracranial arterial aneurysm, predominantly saccular aneurysms, is characterized by an absence of smooth muscle layer and an intimal elastic lamina in the walls of cerebral vessels, resulting in a thin-walled outpouching structure. These lesions are commonly located in the anterior circulation of the circle of Willis (85%) [(10)].

AVMs are marked by a tangle of abnormally formed blood vessels, where arteries are directly connected to veins without an intervening capillary network. These are most commonly located in the region of the middle cerebral artery [(10)].

There is limited definitive information regarding sudden neurologic death caused by ischemic stroke. In this study, data on deaths attributed to ischemic stroke were derived from autopsy findings that provided clear evidence to define the cause of death.

Sudden deaths from nervous system infections account for approximately 1–2% [(1)]. In this study, all 4 cases of infection were diagnosed with bacterial meningitis due to dense neutrophilic infiltrate in the subarachnoid space. However, there was limitation in pertaining microbiologic study. Thus, causative organisms of meningitis in these cases were not identified.

Most common pathogens for bacterial meningitis are S. pneumoniae, N. meningitidis and H. influenzae [(11)]. S. pneumoniae infection has a high fatality rate, ranging from 20% to 37% in high-income countries and reaching as high as 51% in low-income countries [(11)]. Risk factors of bacterial meningitis including age, immune status, social and behavioral factors [(11)].

Bacterial meningitis can be fatal, as evidenced by a study conducted in Denmark, which found that approximately 21% of patients admitted with bacterial meningitis

died within 48 hours of admission [12]. The primary causes of death were brain herniation and septic shock [12].

Sudden death due to brain tumors accounted for approximately 2% of cases in this study, compared to 0.4% reported in previous research [1]. The higher incidence observed in this study may be attributed to cases where the deceased had never received a diagnosis or treatment for a brain tumor, leading to unrecognized progression and ultimately sudden death.

Among the five tumor cases identified in this study, four were meningioma and one case was glioma. Three cases of meningioma were female. This finding aligns with previous studies, which portray meningioma as the most common tumor of the central nervous system, and frequently observed in women than in men [13-14]. Meningioma are predominantly benign tumors attaching to the dura that arise from meningothelial cells [15].

In the context of Thailand, SUDEP diagnosis poses significant challenges. This difficulty arises from limited access to healthcare for some individuals and a lack of awareness about the importance of treatment among others. Consequently, many cases remain untreated and unrecorded in the public health systems. Additionally, in some instances, even the deceased's relatives may be unaware of the individual’s underlying medical conditions.

SUDEP is often diagnosed based on observations of seizure activity prior to death, a documented history of epilepsy treatment, or the presence of antiepileptic medication found with the deceased. However, without prior treatment or medical records, diagnosing SUDEP becomes exceedingly difficult. Furthermore, SUDEP often lacks definitive gross or histological findings to confirm its diagnosis. As a result, the cause of death is frequently attributed to other conditions, with sudden cardiac death being a common misdiagnosis [1,16].

Among 28 cases of hemorrhagic death with positive toxicology findings, 21 were associated with intracranial hemorrhage, including intracerebral and brainstem hemorrhages. Of these, 11 cases were alcohol, while the remaining 10 cases were stimulant drug (amphetamine and methamphetamine). A study has indicated that heavy alcohol consumption is associated with an increased risk of intracranial hemorrhage [7, 17]. While the exact pathophysiological link between alcohol consumption and intracranial hemorrhage remains unclear, alcohol use is known to be associated with hypertension, which is a major risk factor for intracranial hemorrhage [7, 17]. Another study reveals that methamphetamine is associated with an increased risk of hemorrhagic stroke [18-20]. It is believed that the mechanism by which elevated blood pressure caused by methamphetamine use leads to intracranial hemorrhage is similar to the process observed in idiopathic hypertension, where persistently high blood pressure contributes to this phenomenon [20].

Conclusion

Although sudden neurologic death may have a lower incidence than sudden cardiac death, it still accounts for a significant number of fatalities each year. Investigating its incidence and associated risk factors in the population could contribute to long-term primary prevention efforts. In addition, these findings highlight a potential underdiagnosis of SUDEP. This highlights the potential for further advancements to overcome these limitations in Thailand healthcare.

While this study may not fully represent the entire population, it can serve as a foundation for future research and the development of strategies to improve understanding of sudden neurologic deaths.

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APPENDIX 1
INFORMATION FOR AUTHORS

All authors listed in a paper submitted to Asian Archives of Pathology (AAP) must have contributed substantially to the work. It is the corresponding author who takes responsibility for obtaining permission from all co-authors for the submission. When submitting the paper, the corresponding author is encouraged to indicate the specific contributions of all authors (the author statement, with signatures from all authors and percentage of each contribution can be accepted). Examples of contributions include: designed research, performed research, contributed vital new reagents or analytical tools, analysed data, and wrote the paper. An author may list more than one type of contribution, and more than one author may have contributed to the same aspect of the work.

Authors should take care to exclude overlap and duplication in papers dealing with related materials. See also paragraph on Redundant or Duplicate Publication in "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" at http://www.icmje.org/index.html.

The submitted manuscripts will be reviewed by the members of the Editorial Board or the expert reviewers. At the discretion of the Editorial Board, the manuscripts may be returned immediately without full review, if deemed not competitive or outside the realm of interests of the majority of the readership of the Journal. The decision (reject, invite revision, and accept) letter will be coming from the Editorial Board who has assumed responsibility for the manuscript's review. The editor's decision is based not just on technical merit of the work, but also on other factors such as the priority for publication and the relevance to the Journal's general readership. All papers are judged in relation to other submissions currently under consideration.

Categories of Manuscripts

1. Letters to the Editor

The letters to the editor are the reactions to any papers published in AAP. These letters will be reviewed by the Editorial Board and sent to the authors of the original paper with an invitation to respond. Letters and eventual responses will be published together, when appropriate.

- *Word Count: 300 – 500 words (excluding references and figure or table legends)*
- *Abstract: Not required*
- *References: Maximum of 10*
- *Figure or Table: Maximum of 1 (if needed)*

2. Original Articles

The original articles are the researches describing the novel understanding of anatomical pathology, clinical pathology (laboratory medicine), forensic medicine (legal medicine or medical jurisprudence), molecular medicine or pathobiology. Systematic reviews, meta-analyses and clinical trials are classified as articles. The articles should be clearly and concisely written in the well-organised form (see ***Organisation of Manuscripts***): abstract; introduction; materials and methods; results; discussion; and conclusions. The manuscripts that have passed an initial screening by the Editorial Board will be reviewed by two or more experts in the field.

- *Word Count: 3,000 – 5,000 words (excluding abstract, references, and figure or table legends)*
- *Structured Abstract (see* ***Organisation of Manuscripts****): 150 – 200 words*
- *References: Maximum of 150*
- *Figures or Tables: Maximum of 6*

3. Review Articles

The review articles are generally invited by the Editor-in-Chief. They should focus on a topic of broad scientific interest and on recent advances. These articles are peer-reviewed before the final decision to accept or reject the manuscript for publication. Therefore, revisions may be required.

- *Word Count: 3,000 – 5,000 words (excluding abstract, references, and figure or table legends)*
- *Unstructured Abstract: 150 – 200 words*
- *References: Maximum of 150*
- *Figures or Tables: Maximum of 4*

4. Case Reports

AAP limits publication of case reports to those that are truly novel, unexpected or unusual, provide new information about anatomical pathology, clinical pathology (laboratory medicine) or forensic medicine (legal medicine or medical jurisprudence). In addition, they must have educational value for the aforementioned fields. The journal will not consider case reports describing preventive or therapeutic interventions, as these generally require stronger evidence. Case reports that involve a substantial literature review should be submitted as a review article. The submitted case reports will undergo the usual peer-reviewed process.

- *Word Count: 1,200 – 2,000 words (excluding abstract, references, and figure or table legends)*
- *Unstructured Abstract: 150 – 200 words*

- *References: Maximum of 20*
- *Figures or Tables: Maximum of 4*

5. Case Illustrations

Case illustrations are aimed to provide education to readers through multidisciplinary clinicopathological discussions of interesting cases. The manuscript consists of a clinical presentation or description, laboratory investigations, discussion, final diagnosis, and up to 5 take-home messages (learning points). Regarding continuous learning through self-assessment, each of the case illustrations will contain 3 – 5 multiple choice questions (MCQs) with 4 – 5 suggested answers for each question. These MCQs are placed after the final diagnosis and the correct answers should be revealed after the references. The questions and take-home messages (learning points) are included in the total word count. The manuscripts that have passed an initial screening by the Editorial Board will be reviewed by two experts in the field.

- *Word Count: 1,000 – 2,000 words (excluding references and figure or table legends)*
- *Abstract: Not required*
- *References: Maximum of 10*
- *Figures: Maximum of 2*
- *Tables: Maximum of 5*

6. Technical Notes

The technical notes are brief descriptions of scientific techniques used in the anatomical pathology, clinical pathology (laboratory medicine), forensic medicine (legal medicine or medical jurisprudence), molecular medicine or pathobiology. The submitted manuscripts are usually peer-reviewed.

- *Word Count: Maximum of 1,000 words (excluding references and figure or table legends)*
- *Abstract: Not required*
- *References: Maximum of 5*
- *Figures or Tables: Maximum of 2*

Organisation of Manuscripts

1. General Format

The manuscripts written in English language are preferable. However, Thai papers are also acceptable, but their title pages, abstracts, and keywords must contain both Thai and English. These English and Thai manuscripts are prepared in A4-sized Microsoft Word documents with leaving 2.54-cm (1-inch) margins on all sides. All documents are required to be aligned left and double-spaced throughout the entire manuscript. The text should be typed in 12-point regular Times New Roman font for English manuscript and 16-point regular TH SarabunPSK font for Thai manuscript.

The running titles of English and Thai manuscripts are placed in the top left-hand corner of each page. They cannot exceed 50 characters, including spaces between words and punctuation. For the header of English paper, the running title will be typed in all capital letters. The page number goes on the top right-hand corner.

Footnotes are not used in the manuscripts, but parenthetical statements within text are applied instead and sparingly. Abbreviations should be defined at first mention and thereafter used consistently throughout the article. The standard abbreviations for units of measure must be used in conjunction with numbers.

All studies that involve human subjects should not mention subjects' identifying information (e.g. initials) unless the information is essential for scientific purposes and the patients (or parents or guardians) give written informed consent for publication.

2. Title Page

The title page is the first page of the manuscripts and must contain the following:

- The title of the paper (not more than 150 characters, including spaces between words)
- The full names, institutional addresses, and email addresses for all authors (If authors regard it as essential to indicate that two or more co-authors are equal in status, they may be identified by an asterisk symbol with the caption "These authors contributed equally to this work" immediately under the address list.)
- The name, surname, full postal address, telephone number, facsimile number, and email address of the corresponding author who will take primary responsibility for communication with AAP.
- Conflict of interest statement (If there are no conflicts of interest for any author, the following statement should be inserted: "The authors declare that they have no conflicts of interest with the contents of this article.")

3. Abstract

A structured form of abstract is used in all Original Article manuscripts and must include the following separate sections:

- *Background: The main context of the study*
- *Objective: The main purpose of the study*
- *Materials and Methods: How the study was performed*
- *Results: The main findings*
- *Conclusions: Brief summary and potential implications*
- *Keywords: 3 – 5 words or phrases (listed in alphabetical order) representing the main content of the article*

4. Introduction

The Introduction section should clearly explain the background to the study, its aims, a summary of the existing literature and why this study was necessary or its contribution to the field.

5. Materials and Methods

The Materials and Methods section must be described in sufficient detail to allow the experiments or data collection to be reproduced by others. Common routine methods that have been published in detail elsewhere should not be described in detail. They need only be described in outline with an appropriate reference to a full description. Authors should provide the names of the manufacturers and their locations for any specifically named medical equipment and instruments, and all chemicals and drugs should be identified by their systematic and pharmaceutical names, and by their trivial and trade names if relevant, respectively. Calculations and the statistical methods employed must be described in this section.

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The Discussion section should focus on the interpretation and the significance of the findings against the background of existing knowledge. The discussion should not repeat information in the results. The authors will clearly identify any aspects that are novel. In addition, there is the relation between the results and other work in the area.

8. Conclusions

The Conclusions section should state clearly the main summaries and provide an explanation of the importance and relevance of the study reported. The author will also describe some indication of the direction future research should take.

9. Acknowledgements

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Thanks to anonymous reviewers are not allowed. If you do not have anyone to acknowledge, please write "Not applicable" in this section.

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- *Journal article*

1. Sibai BM. Magnesium sulfate is the ideal anticonvulsant in preeclampsia – eclampsia. Am J Obstet Gynecol 1990; 162: 1141 – 5.

- *Books*

  2. Remington JS, Swartz MN. Current Topics in Infectious Diseases, Vol 21. Boston: Blackwell Science Publication, 2001.

- *Chapter in a book*

  3. Cunningham FG, Hauth JC, Leveno KJ, Gilstrap L III, Bloom SL, Wenstrom KD. Hypertensive disorders in pregnancy. In: Cunningham FG, Hauth JC, Leveno KJ, Gilstrap L III, Brom SL, Wenstrom KD, eds. Williams Obstetrics, 22nd ed. New York: McGraw-Hill, 2005: 761 – 808.

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- *Results*
- *Discussion*
- *Conclusions*
- *Acknowledgements*
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- *Conclusions*
- *Acknowledgements*
- *References*
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- *Acknowledgements*
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- *Figure Legend (s)*
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- *Take-Home Messages (Learning Points)*
- *Acknowledgements*
- *References*
- *Correct Answers to MCQs*
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