Heliyon 9 (2023) e19984

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

An audit of autopsy-confirmed diagnostic errors in perinatal deaths: What are the most common major missed diagnoses

Yinwen Xu [a,b,1], Chenchen Cheng [a,1], Fengyun Zheng [c], Hexige Saiyin [d], Pingzhao Zhang [a], Wenjiao Zeng [a], Xiuping Liu [a,**], Guoyuan Liu [a,*]

[a] Department of Pathology, School of Basic Medical Sciences, Fudan University, Shanghai, China
[b] Department of Forensic Medicine, School of Basic Medical Sciences, Fudan University, Shanghai, China
[c] Institutes of Biomedical Sciences, Shanghai Medical College, Fudan University, Shanghai, China
[d] The State Key Laboratory of Genetic Engineering, Fudan University, Shanghai, China

ARTICLE INFO

Keywords:
Autopsy pathology
Perinatal death
Diagnosis discrepancy
Cause of death
Neonatal respiratory distress syndrome (NRDS)

ABSTRACT

Perinatal autopsies are essential to establish the cause of stillbirth or neonatal death and improve clinical practice. Limited studies have provided detailed major missed diagnoses of perinatal deaths in current clinical practice. In this retrospective audit of 177 perinatal autopsies including 99 stillbirths and 78 neonatal deaths with complete pathologic evaluation, 66 cases (21 Class I and 45 Class II diagnostic errors) were revealed as major discrepancies (37.3%), with complete agreements in 80 cases (45.2%). The difference in major discrepancies between stillbirth and neonatal death groups was significant ($P < 0.001$), with neonatal deaths being more prone to Class I errors. Various respiratory diseases (25/66, 37.9%) and congenital malformations (16/66, 24.2%) accounted for the majority of missed diagnoses (41/66, 62.1%). More importantly, neonatal respiratory distress syndrome (NRDS) was the most common type I missed diagnosis (7/8, 87.5%), markedly higher than the average 11.9% of all Class I errors. Our findings suggest that there are high disparities between clinical diagnoses and autopsy findings in perinatal deaths, and that various respiratory diseases are mostly inclined to cause major diagnostic errors. We first demonstrated that NRDS is the most common type I missed diagnosis in perinatal deaths, which clinicians should pay special attention to in practice.

1. Introduction

Autopsies of perinatal deaths, including stillbirths and neonatal deaths, are essential for ascertaining the cause of death, providing information for parents counseling regarding future pregnancies, and improving the clinical practice [1–3]. Nevertheless, the decline of clinical autopsies, including perinatal autopsies, has been presented worldwide in recent decades as a result of complex social and cultural phenomena [1,4–6]. In addition to parental refusal [7], immunological, genetic and molecular technology breakthroughs, and the reluctance of pathologists to perform autopsies which are considered a burden of their routine work, may all have contributed to this decline [5].

* Corresponding author.
** Corresponding author. Department of Pathology, School of Basic Medical Sciences, Fudan University, Shanghai 200040, China.
E-mail addresses: xpliu1228@fudan.edu.cn (X. Liu), gyliu@fudan.edu.cn (G. Liu).
[1] These authors equally contributed to this work.

https://doi.org/10.1016/j.heliyon.2023.e19984
Received 17 February 2023; Received in revised form 21 July 2023; Accepted 7 September 2023
Available online 9 September 2023

Table 1
Description of diagnosis discrepancy classes.

Type of discrepancies	Classification of diagnosis error	Definition	Examples
Major	I	Directly related to death; if recognized, may have altered treatment or survival	Unrecognized NRDS or aspiration pneumonia of the neonates who were in hospitals; undiagnosed nonintrapartum trauma or milk aspiration
	II	Directly related to death; if recognized, would not have altered treatment or survival	Unrecognized congenital pulmonary hypoplasia; undiagnosed interstitial pneumonia and pulmonary hemorrhage with SGA (body weight 1750g)
Minor	III	Incidental autopsy finding not directly related to death but related to terminal disease process	Known congenital hypertrophic pyloric stenosis with undiagnosed interstitial pneumonia; congenital thymic dysplasia in neonate with unrecognized interstitial pneumonia
	IV	Incidental autopsy finding unrelated to cause of death, or incidental autopsy finding contributing to death in an already terminally ill patient	Unlethal congenital anomalies such as symptomless Meckel's diverticulum; placental villous degeneration of a single fetal death in twin pregnancies
Non-discrepancy	V	Clinical and autopsy diagnoses in complete agreement	
Non-classifiable cases	VI	Necropsy was unsatisfactory with no clear findings and no diagnosis could be established after review of clinical and necropsy data	Intrauterine asphyxia with unascertained cause

Abbreviations: SGA, small for gestational age. Examples include the cases in this study.

Despite the continuing decline of perinatal autopsy, relevant discrepancies between diagnostic presumptions and autopsy findings existed and have been reported constantly [2,3,8,9]. However, few studies have provided detailed major missed diagnoses of perinatal deaths, including both clinical and medicolegal autopsies, which are encountered in current daily practice. The extent to which complete systematic perinatal autopsy influence obstetrics, gynecology, and neonatology, and how often clinical diagnoses are correct in perinatal deaths in a realistic clinical practice-oriented setting, remain unknown. Thus, a consecutive perinatal complete autopsy series spanning a 23-year period was analyzed at our autopsy center to investigate the diagnostic composition, evaluate the discrepancies between clinical diagnoses and postmortem autopsy findings, and identify the most common major missed diagnoses in the included perinatal deaths.

2. Materials and methods

2.1. Cases selection

The medical and necropsy records of 177 perinatal deaths (from January 1, 1997 to September 31, 2020), including stillbirths (intrauterine death or death during delivery with a gestational age of $\geq$28 weeks [1]) and neonatal deaths (premature or term newborns that died within the first month of life [2,10]), were retrospectively analyzed. The studied cases included those involved in medical disputes in several hospitals in Shanghai, as well as those the causes of deaths were unclear, and their parents were counseled directly towards the benefits of autopsy for future pregnancy. All patients underwent an autopsy at the Department of Pathology, School of Basic Medical Sciences, Fudan University, Shanghai, China. Informed parental consent for autopsy was obtained in all cases. This study was approved by the Medicine Ethics Committee of the School of Basic Medical Sciences, Fudan University.

2.2. Analysis of reports

The age, sex, clinical diagnosis or symptoms, and necropsy diagnosis in each case were recorded. Full copies of the medical records and related medical information on the maternal/obstetric history were routinely requested from the hospitals or their relatives. The gross description of the autopsy specimen included body weight, crown-heel length (CHL), external appearance, and abnormalities of all viscera, including the brain. In cases without accurate clinical information, the gestational age was estimated based on body weight or CHL [11]. Complete necropsy, including the histological assessment of each organ, was performed by three pathologists in each case. Placental and umbilical cord specimens were evaluated macroscopically and microscopically. The cause of death and the appropriateness of clinical management for each case were discussed at clinico-pathological conferences (CPC) attended by clinicians and consultant pathologists as previously described [4].

Necropsy diagnoses were grouped according to International Classification of Disease, 10th edition (ICD-10): complications of maternal illness, complications of placenta, cord and membrane, perinatal respiratory diseases (i.e., respiratory disorders specific to the perinatal period), perinatal infection, fetal and neonatal hemorrhagic and hematological disorders, congenital malformations, pulmonary diseases (excluding certain conditions originating in the perinatal period and certain infectious and parasitic diseases), miscellaneous (remaining diagnoses), and unknown (intrauterine asphyxia with unascertained cause).

When several important findings were included in a single case, we identified a fundamental finding, that was also the underlying cause of death, as the final necropsy diagnosis. For example, a stillbirth case with clinical information of shoulder dystocia and maternal gestational diabetes mellitus, which had autopsy findings of intrauterine asphyxia, velamentous placenta, hemangioma of the umbilical cord, and macrosomia (4178 g), was categorized as a complication of maternal illness. In most cases, an integral chain of events (underlying to intermediate to immediate causes of death) was constructed. Those without a well-defined underlying cause of deaths, were finally classified as having negative necropsies, even though they had pathological evidence of an immediate cause of death, such as intrauterine asphyxia, as mentioned above.

The discrepancy occurrence and its degree for each case were determined according to the method (Table 1) of Goldman et al. [12], a modification of Battle et al. [13], and as non-classifiable cases [4,14] by three independent investigators with delicate analysis of the clinical information, necropsy findings, autopsy-based cause of death, and CPC discussion notes of the included cases, as previously reported [4]. Conflicts were resolved through discussion until an agreement was reached.

2.3. Data analysis

In this study, a major diagnosis was designated to explain the cause of death for each case, and only the main diagnosis that was directly involved in perinatal death was compared (either maternal causes or fetal/neonatal causes) and did not consider minor discrepancies because in the practice of perinatal medicine, it is the top priority of obstetricians and pediatricians to identify problems that threaten the fetus and newborn's lives rather than focusing on non-urgent problems. The overall frequencies of major errors (Class I + II), and Class I errors, and errors in the different diagnosis and death groups were calculated. The difference in the distribution of discrepancy classification between different gestational age groups, sex groups, and death type groups was compared using the Spearman correlation test with the SPSS V.15.0 statistical software package. All reported P values were two sided and $P \leq 0.05$ was considered significant.

3. Results

3.1. Characteristics of study cases

In total, 177 perinatal deaths (99 stillbirths and 78 neonatal deaths) were included in this study. The male-to-female ratio in autopsy cases was 1.19:1. Most cases (127 of 177, 70.6%) were full term, and the remaining 50 cases (29.4%) were preterm. Detailed data of each case including sex, gestational age, clinical diagnosis or symptoms, main necropsy diagnosis, primary cause of death, and discrepancy classification, are listed in Supplementary Table S1.

3.2. Primary causes of the studied perinatal deaths

Of the nine necropsy diagnosis groups (Table 2) based on ICD-10, the most common primary causes of the included 177 perinatal deaths were complications of placenta, cord and membrane (73 cases, 41.2%), followed by perinatal respiratory diseases (27 cases, 15.3%), congenital malformations (23 cases, 13.0%, Supplementary Table S2), and complications of maternal illness (10 cases, 5.6%). When stratified by death type, complications of placenta, cord and membrane (61/99, 61.6%) and complications of maternal illness (9/99, 9.1%) accounted for most stillbirth cases (70.7%), whereas perinatal respiratory diseases (26/78, 33.3%) and congenital malformations (17/78, 21.8%) were the top two necropsy diagnoses for neonatal deaths. Additionally, the causes of 18 intrauterine asphyxia cases (15 stillbirths and 3 neonatal deaths) remained unknown even after complete necropsy in each case.

Notably, the 10 cases of complications of maternal illness included 4 cases of intrahepatic cholestasis during pregnancy, 2 cases of gestational diabetes mellitus, 2 cases of pregnancy-induced hypertension syndrome, and 1 case of subclinical hypothyroidism. Diagnoses were based on autopsy findings of the placenta and fetus, with information on the maternal/obstetric history of each case (Supplementary Table S1).

In total, 35 cases (19.8% of all included cases) had congenital malformations (Supplementary Table S2) in this study. Among them, 22 cases of anomalies were lethal, and were the main causes of those perinatal deaths, with congenital cardiac defects (13/22, 59.1%) accounting for most cases (Supplementary Table S2).

3.3. Discrepancies between clinical diagnoses and autopsy findings

Detailed data on the diagnostic discrepancy classification for each case are listed in the Supplementary Table S1. In total, 66 cases (37.3%) were revealed as major discrepancies, including 21 cases (11.9%) classified as Class I errors, and 45 cases (25.4%) as Class II errors (Table 2). The occurrence of major and Class I errors differed among the nine diagnostic groups (Table 2).

Eighty cases (45.2%) were classified as Class V discrepancies with complete concordance between clinical diagnoses and postmortem findings, and 18 (10.2%) cases of intrauterine asphyxia with unascertained cause were classified as Class VI discrepancies (Table 2). Thirteen cases were classified as having minor discrepancies with a sum of Class III and Class IV missed diagnoses (Supplementary Table S1).

The distribution of the six diagnostic discrepancies differed between the stillbirths and neonatal deaths (Fig. 1). There was a lower frequency of major diagnostic errors in the stillbirth group (Class I, 0; Class II, 25.3%; total 25.3%) than in the neonatal death group

Table 2
Distribution of the primary causes of death, major diagnostic errors and Class I errors of the study cases.

Diagnosis	No. of cases	Stillbirths No. (%)	Neonatal deaths No. (%)	Major errors No. (%)	Class I errors No. (%)
Total	**177**	**99**	**78**	**66(37.3)**	**21(11.9)**
Complications of maternal illness	**10**	**9(9.1)**	**1(1.3)**	**0(0)**	**0(0)**
Complications of placenta, cord and membrane	**73**	**61(61.6)**	**12(15.4)**	**13(17.8)**	**0(0)**
Perinatal respiratory diseases	**27**	**1(0.1)**	**26(33.3)**	**19(70.4)**	**11(40.7)**
NRDS (Neonatal respiratory distress syndrome)	8	0	8	7	7
Neonatal aspiration syndromes (amniotic fluid, meconium, milk)	13	0	13	8	4
Perinatal pulmonary hemorrhage	5	1	4	3	0
Atelectasis	1	0	1	1	0
Perinatal infection	**7**	**6(0.6)**	**1(1.3)**	**6(85.7)**	**0(0)**
Fetal and neonatal hemorrhagic and hematological disorders	**4**	**1(0.1)**	**3(2.3)**	**2(50)**	**1(25)**
Hemolytic diseases (erythroblastosis fetalis, hydrops fetalis)	2	1	1	2	1
Intracranial hemorrhage of fetus and newborn (nontraumatic)	2	0	2	0	0
Congenital malformations	**23**	**6(0.6)**	**17(21.8)**	**16(69.6)**	**1(4.3)**
Pulmonary diseases	**8**	**0(0)**	**8(10.2)**	**6(75)**	**4(50)**
Pneumonia (Interstitial pneumonia, lobular pneumonia, fungal) pneumonia)	6	0	6	4	2
Airway obstruction (aspiration of milk)	2	0	2	2	2
Miscellaneous	**7**	**0(0)**	**7(9.0)**	**4(57.1)**	**4(57.1)**
Dystocia	3	0	3	1	1
Multiple traumatic injuries (accident or nonintrapartum trauma)	2	0	2	2	2
Others (choroid plexus papilloma, drug-induced liver injury)	2	0	2	1	1
Unknown (Intrauterine asphyxia with unascertained cause)	**18**	**15(15.2)**	**3(3.8)**	**0(0)**	**0(0)**

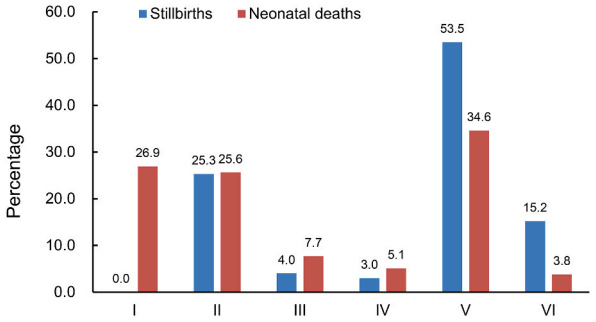

Fig. 1. Distribution of discrepancy Classes I–VI within the stillbirth and neonatal death groups.

(Class I, 26.9%; Class II, 25.6%; total 52.5%). While stillbirth cases were more inclined to occur with Class VI discrepancy, with 15.2% (15/99) in the stillbirth group and 3.8% (3/78) in neonatal death group (Fig. 1).

The probability of occurrence of the six different diagnostic discrepancies did not depend on sex, or gestational age (premature or full-term). However, it was related to different death groups with Spearman correlation test (rho = 0.375, $P < 0.001$). There was significant difference between the stillbirth and neonatal death groups in terms of major discrepancies (Class I and II diagnostic errors) (rho = 0.320, $P < 0.001$), and neonatal deaths were more prone to occur Class I diagnostic errors ($P < 0.001$) according to the Pearson $\chi 2$ test (Table 3).

3.4. Most common major and class I missed diagnoses in prenatal deaths

As shown in Table 2, various respiratory diseases, including perinatal (19 cases) and general respiratory diseases (6 cases), were the most common diagnoses (25/66, 37.9%) of major missed errors (Classed I and II), followed by congenital malformations (16/66, 24.2%), which accounted for most cases of Class II missed diagnoses (15/45, 33.3%) of perinatal deaths.

More importantly, perinatal respiratory diseases constituted the majority (15/21, 71.7%) of class I missed diagnoses of perinatal deaths (Table 3), which included seven cases of neonatal respiratory distress syndrome (NRDS) and four cases of neonatal aspiration syndromes, followed by general respiratory diseases (two cases of airway obstruction caused by milk inhalation, two cases of pneumonia). Among these, NRDS was the most common type I missed diagnosis (7/8, 87.5%), markedly higher than the average 11.9% (21/177) of all Class I errors in the study cases (Table 4). Additionally, two cases of multiple traumatic injuries (accidents or non-intrapartum trauma) were classified as Class I errors.

4. Discussion

Consisting with previous reports on high diagnostic disparities between clinical diagnoses and postmortem examinations in different clinical settings [2–4,15], our findings of high rate of diagnostic errors in perinatal deaths with full postmortem examination suggest that autopsy plays a crucial role in uncovering the true cause of perinatal deaths even in the current situation of considerable improvement in modern medicines.

In this study, the major diagnostic discrepancy rate (36.7%) and Class I error rate (11.7%) of perinatal deaths were higher than the median error rate (23.5%) for major errors and Class I errors (9.0%) in a previous systemic review of autopsy-detected diagnostic error of different case mixes, including adult, pediatric and neonatal patients [15]. The results suggest that perinatal death cases are more

Table 3
Distribution of discrepancy classification in different sex or gestational age or death type groups of the study cases.

Study group	Total	No. of different discrepancy classes (%)					
		I [d]	II [d]	III	IV	V	VI
Sex [a]							
Male	96(54.2)	10(5.6)	29(16.4)	3(1.7)	2(1.1)	43(24.3)	9(6.1)
Female	81(45.8)	11(6.2)	16(9.0)	6(3.4)	2(1.1)	37(20.9)	9(3.9)
Gestation Age [b]							
Premature	50(28.2)	5(2.8)	15(8.5)	3(1.7)	2(1.1)	19(10.7)	6(3.4)
Full term	127(71.8)	16(9.0)	30(16.9)	6(3.4)	2(1.1)	61(34.5)	12(6.8)
Death type [c]							
Stillbirths	99(55.9)	0(0.0)	25(14.1)	4(2.3)	2(1.1)	53(29.9)	15(8.5)
Neonatal deaths	78(44.1)	21(11.9)	20(11.3)	5(2.8)	2(1.1)	27(15.3)	3(1.7)

[a] P of differences between male/female groups = 0.674 by Spearman correlation test, rho = 0.032.
[b] P of differences between different age groups = 0.768 by Spearman correlation test, rho = 0.022.
[c] P of differences between Stillbirths/Neonatal deaths groups <0.001 by Spearman correlation test, rho = 0.375.
[d] P of the differences of Class I and Class II discrepancy between Stillbirths/Neonatal deaths groups <0.001 by Pearson $\chi 2$ test.

Table 4
Top 5 frequent Class I missed diagnoses (case number ≥2) in this study.

Diagnosis	No. of Class I error	No. of cases	Percentage
NRDS	7	8	87.5%
Aspiration syndrome of newborn	4	13	30.8%
Airway obstruction (Aspiration of milk)	2	2	100%
Multiple traumatic injuries	2	2	100%
Pneumonia	2	6	33.3%

Abbreviations: NRDS: neonatal respiratory distress syndrome.

prone to major diagnosis errors. Furthermore, in the case of neonatal deaths, the major discrepancy rate (52.5%, including 26.9% of Class I errors) was substantially higher than the range of 6–26.9% in previous reports in neonatal ICU [9,15]. The higher diagnostic errors may be because the neonatal deaths cases included in this study were not confined to NICU where neonates were in intense care and had easier access to resuscitation, but in broader settings, including general neonatal wards, where neglected deaths are more inclined to occur due to a lower level of care. Furthermore, most cases included in our study involved medical disputes, which may have increased the possibility of clinical diagnostic errors and led to selection bias.

Perinatal and general respiratory diseases accounted for top two most frequent major diagnostic errors in perinatal deaths. The various respiratory diseases are difficult to diagnose because the clinical manifestations are often nonspecific, and the radiological appearance can be identical [16]. NRDS (7/8, 87.5%), neonatal aspiration syndromes (4/13, 30.8%), airway obstruction due to aspiration of milk (2/2, 100%) and pneumonia (2/6, 33.3%) accounted for the majority (15/21, 71.7%) of Class I missed diagnoses (Table 3). Thus, in practice, obstetricians and pediatricians should pay attention to respiratory diseases of neonates, particularly the risk of developing NRDS, the most common Class I missed diagnosis, in the premature neonates with a very low birth weight [17,18]. Although NRDS is likely to cause neonatal respiratory failure and neonatal mortality, newly developed valuable non-invasive techniques such as lung ultrasound, which can diagnose NRDS more accurately and specifically than conventional chest X-rays and predict surfactant administration [17], and a new strategy for surfactant therapy [18], may be useful for pediatricians to deal with NRDS in a timely and accurate manner and to improve the neonatal survival rate.

Noticeably, the necropsy diagnosis spectra of stillbirths and neonatal deaths are different (Table 2), despite the fact that, in quite a few cases, intrauterine asphyxia caused by complications of the placenta, cord and membrane could cause stillbirth, or low Apgar scores or severe respiratory distress, followed by neonatal death [16]. The majority of stillbirths (61.6%) were diagnosed as complications of the placenta and cord, which falls within the reported ranges of 23–65% of stillbirth cases in large cohorts [1,19]. Perinatal respiratory diseases (33.3%) and congenital malformations (21.8%) accounted for more than 50% of the included neonatal deaths. Overall, the necropsy diagnostic composition of perinatal deaths in this study was similar to that of previous reports [19–21].

The present necropsy study had some limitations. First, this study was a single-center retrospective review of perinatal death cases, and the included neonatal cases were mostly involved in medical disputes rather than clinical autopsy cases; thus, there was an inherent selection bias and a higher incidence of major diagnostic errors, as mentioned above. Second, the study covered a period of 23 years, during which the diagnostic methods had great improvements in modern medicine. This also contributed to a higher incidence of major diagnostic errors. However, these results may provide more information to obstetricians and pediatricians in areas where diagnostic tools are scarce or unavailable. Third, 10.2% of all perinatal cases had no histologic confirmation of diagnosis even after complete necropsy of each case. Negative necropsies are common among perinatal deaths [9,10,22], because of the inherent features of autopsy, which can only reveal the underlying pathogenesis by morphological observation, and miss those with metabolic or cardiac electrical dysfunction. A combination of autopsy examination, laboratory tests such as microbiological examination, and genetic evaluation may help unravel the causes of some unexplained stillbirths, neonatal demise [23], and some congenital anomalies.

5. Conclusion

In summary, there is a high rate of autopsy-confirmed diagnostic errors in perinatal deaths. NRDS is the most frequently major missed diagnosis in perinatal deaths, and obstetricians and pediatricians should pay special attention to it in practice. Our study confirms and emphasizes the necessity and usefulness of perinatal autopsies in obstetrics and neonatal medicine.

Funding

This work was supported by STI2030-Major Project #2021ZD0201100 Task 4 #2021ZD0201104 from Ministry of Science and Technology of the People's Republic of China.

Ethics approval

This retrospective study was conducted according to the Declaration of Helsinki and was approved by Medicine Ethics Committee of School of Basic Medical Sciences, Fudan University (IRB Approval no. 2022-C004).

Author contribution statement

Yinwen Xu: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Chenchen Cheng: Performed the experiments; Analyzed and interpreted the data.
Fengyun Zheng:Contributed reagents, materials, analysis tools or data.
Hexige Saiyin: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.
Pingzhao Zhang: Contributed reagents, materials, analysis tools or data.
Wenjiao Zeng: Analyzed and interpreted the data; Wrote the paper.
Xiuping Liu: Conceived and designed the experiments; Wrote the paper.
Guoyuan Liu: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e19984.

References

[1] K.F. Kock, V. Vestergaard, M. Hardt-Madsen, E. Garne, Declining autopsy rates in stillbirths and infant deaths: results from Funen County, Denmark, 1986-96, J. Matern. Fetal Neonatal Med. 13 (2003) 403–407, https://doi.org/10.1080/jmf.13.6.403.407.
[2] N. Nese, Y. Bulbul, Diagnostic value of perinatal autopsies: analysis of 486 cases, J. Perinat. Med. 46 (2018) 175–181, https://doi.org/10.1515/jpm-2016-0396.
[3] M. Sorop-Florea, R.N. Ciurea, M. Ioana, A.E. Stepan, G.A. Stoica, F. Tanase, et al., The importance of perinatal autopsy. Review of the literature and series of cases, Rom. J. Morphol. Embryol. 58 (2017) 323–337.
[4] D. Liu, R. Gan, W. Zhang, W. Wang, H. Saiyin, W. Zeng, et al., Autopsy interrogation of emergency medicine dispute cases: how often are clinical diagnoses incorrect? J. Clin. Pathol. 71 (2018) 67–71, https://doi.org/10.1136/jclinpath-2017-204484.
[5] M. Dell'Aquila, G. Vetrugno, S. Grassi, E. Stigliano, A. Oliva, G. Rindi, et al., Postmodernism and the decline of the clinical autopsy, Virchows Arch. 479 (2021) 861–863, https://doi.org/10.1007/s00428-021-03166-7.
[6] M.H. Zhu, D.H. Yu, Fluctuations in the rate of autopsy in China, Chin Med J (Engl) 124 (2011) 3403–3407.
[7] R. Adappa, S. Paranjothy, Z. Roberts, P.H. Cartlidge, Perinatal and infant autopsy, Arch Dis Child Fetal Neonatal 92 (2007) F49–F50, https://doi.org/10.1136/adc.2005.091447.
[8] J.W. Custer, B.D. Winters, V. Goode, K.A. Robinson, T. Yang, P.J. Pronovost, et al., Diagnostic errors in the pediatric and neonatal ICU: a systematic review, Pediatr. Crit. Care Med. 16 (2015) 29–36, https://doi.org/10.1097/PCC.0000000000000274.
[9] R. Widmann, R. Caduff, L. Giudici, Q. Zhong, A. Vogetseder, R. Arlettaz, et al., Value of postmortem studies in deceased neonatal and pediatric intensive care unit patients, Virchows Arch. 470 (2017) 217–223, https://doi.org/10.1007/s00428-016-2056-0.
[10] D.N. Saller Jr., Lesser KB, Harrel U, Rogers BB, Oyer CE. The clinical utility of the perinatal autopsy, JAMA 273 (1995) 663–665, https://doi.org/10.1001/jama.273.8.663.
[11] J.G. Archie, J.S. Collins, R.R. Lebel, Quantitative standards for fetal and neonatal autopsy, Am. J. Clin. Pathol. 126 (2006) 256–265, https://doi.org/10.1309/FK9D-5WBA-1UEP-T5BB.
[12] L. Goldman, R. Sayson, S. Robbins, L.H. Cohn, M. Bettmann, M. Weisberg, The value of the autopsy in three medical eras, N. Engl. J. Med. 308 (1983) 1000–1005, https://doi.org/10.1056/NEJM198304283081704.
[13] R.M. Battle, D. Pathak, C.G. Humble, C.R. Key, P.R. Vanatta, R.B. Hill, et al., Factors influencing discrepancies between premortem and postmortem diagnoses, JAMA, J. Am. Med. Assoc. 258 (1987) 339–344.
[14]] K. Sonderegger-Iseli, S. Burger, J. Muntwyler, F. Salomon, Diagnostic errors in three medical eras: a necropsy study, Lancet 355 (2000) 2027–2031, https://doi.org/10.1016/s0140-6736(00)02349-7.
[15] K.G. Shojania, E.G. Burton, K.M. McDonald, L. Goldman, Changes in rates of autopsy-detected diagnostic errors over time - a systematic review, JAMA, J. Am. Med. Assoc. 289 (2003) 2849–2856, https://doi.org/10.1001/jama.289.21.2849.
[16] M.D. Nissen, Congenital and neonatal pneumonia, Paediatr. Respir. Rev. 8 (2007) 195–203, https://doi.org/10.1016/j.prrv.2007.07.001.
[17] H. Pang, B. Zhang, J. Shi, J. Zang, L. Qiu, Diagnostic value of lung ultrasound in evaluating the severity of neonatal respiratory distress syndrome, Eur. J. Radiol. 116 (2019) 186–191, https://doi.org/10.1016/j.ejrad.2019.05.004.
[18] R. Zhuo, P. Rong, J. Wang, R. Parvin, Y. Deng, The potential role of bioactive plasmalogens in lung surfactant, Front. Cell Dev. Biol. 9 (2021), 618102, https://doi.org/10.3389/fcell.2021.618102.
[19] J.M. Page, R.M. Silver, Evaluation of stillbirth, Curr. Opin. Obstet. Gynecol. 30 (2018) 130–135, https://doi.org/10.1097/GCO.0000000000000441.
[20] J. Man, J.C. Hutchinson, A.E. Heazell, M. Ashworth, S. Levine, N.J. Sebire, Stillbirth and intrauterine fetal death: factors affecting determination of cause of death at autopsy, Ultrasound Obstet. Gynecol. 48 (2016) 566–573, https://doi.org/10.1002/uog.16016.
[21] G. Stillbirth Collaborative Research Network Writing, Causes of death among stillbirths, JAMA 306 (2011) 2459–2468, https://doi.org/10.1001/jama.2011.1823.
[22] C.P. Bhale, A. Vare, A. Gupta, Fetal autopsy-categories and causes of death at a tertiary care center, Am. J. Forensic Med. Pathol 42 (2021) 12–15, https://doi.org/10.1097/PAF.0000000000000608.
[23] M.H. Wojcik, D. Brodsky, J.E. Stewart, J. Picker, Peri-mortem evaluation of infants who die without a diagnosis: focus on advances in genomic technology, J. Perinatol. 38 (2018) 1125–1134, https://doi.org/10.1038/s41372-018-0187-7.