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par

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Impact du choix des organes prélevés en anatomopathologie sur la conclusion médico-légale : Faut-il prélever le cœur et le cerveau en entier ?
Etat des lieux à l'Institut Médico-Légal du CHU de TOURS (2020 – 2022)

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Résumé

Introduction : L'analyse histologique après une autopsie médico-légale n'est pas systématique en France. Le médecin légiste prélève les organes (en entier ou des fragments) qui lui paraissent pertinents mais la décision de l'analyse revient au magistrat responsable de l'enquête. Il n'existe pas de recommandations validées concernant l'échantillonnage d'organes en anatomopathologie. Toutefois, ces organes n'étant pas restitués aux défunts, nous nous sommes confrontés récemment aux plaintes de familles trouvant des prélèvements systématiques injustifiés. Dans ce contexte, nous avons mené une étude dont l'objectif était de déterminer quels organes prélevés pour analyses anatomopathologiques avaient un impact sur la conclusion médico-légale, et plus particulièrement s'il y avait un intérêt à prélever le cœur et le cerveau en entier.

Matériel et méthodes : Nous avons mené une étude sur les comptes rendus d'autopsie et d'analyse anatomopathologique des corps autopsiés à l'Institut Médico-Légal de Tours entre 2020 et 2022. L'utilité des prélèvements systématiques d'organes lors d'autopsies médico-légales a été évaluée, en classant les conclusions médico-légales en 7 catégories : 4 dites « utiles » (diagnostic, discordante, caractéristique lésionnelle, état antérieur) et 3 « inutiles » (confirme, non contributif, lésions mineures).

Résultats : Sur 142 dossiers analysés, le cœur a été prélevé en entier dans 94 % des cas et le cerveau en entier dans 87% des cas. L'analyse anatomopathologique de ces organes a permis la catégorisation des conclusions médico-légales dans une des catégories dites « utiles » dans 44 % des cas pour le cœur et 14 % des cas pour le cerveau. Par ailleurs, la réalisation de l'examen histopathologique s'est avérée utile dans 49 % des cas, peu importe les organes prélevés, fournissant des informations diagnostiques cruciales dans 18 % des cas, caractérisant des lésions dans 20 % des cas, et révélant des conditions médicales préexistantes ayant pu participer au décès dans 10 % des cas.

Discussion : Parmi les éléments d'intérêt médico-légaux apportés par le prélèvement du cœur et le cerveau, il est probable que dans la majorité des cas, un examen macroscopique de qualité et un échantillonnage ciblé auraient mené à la même conclusion. De plus, dans 51 % des cas, l'expertise anatomopathologique n'a pas apporté d'éléments supplémentaires aux données macroscopiques, questionnant l'utilité des prélèvements systématiques. Ainsi, nous proposons un protocole d'échantillonnage standardisé visant à équilibrer la qualité des investigations médico-légales avec les contraintes pratiques actuelles.

Mots clés : Médecine légale – Autopsie médico-légale – Anatomopathologie médico-légale – Prélèvements d'organes – Pratiques autopsiques – Enquête décès

Abstract

Impact of the choice of organs sampled in pathology on the forensic conclusion: should heart and brain be retained whole? An overview of practices at the medico-legal Institute of the University Hospital of Tours (2020-2022).

Introduction : In France, histological analysis following a forensic autopsy is not systematically performed. Forensic doctors select whole organs or tissue samples they deem relevant, but the final decision to conduct analysis rests with the investigating magistrate. There are no established guidelines for organ sampling in pathology. Recently, we've faced complaints from families who question the justification for systematic sampling, as these organs are not returned to the deceased. In light of this, we conducted a study to determine which sampled organs significantly impacted forensic conclusions, with a particular focus on the value of retaining the entire heart and brain.

Materials and methods : We reviewed autopsy and pathological analysis reports from bodies examined at the Medico-legal Institute of Tours between 2020 and 2022. We evaluated the usefulness of systematic organ sampling during forensic autopsies by categorizing forensic conclusions into 7 groups: 4 "useful" (diagnostic, discordant, injury characterization, prior health condition) and 3 "not useful" (confirms autopsy findings, non-contributory, minor lesions).

Results : Of 142 cases analyzed, the entire heart was retained in 94% of cases and the entire brain in 87%. Pathological analysis of these organs yielded "useful" conclusions in 44% of heart cases and 14% of brain cases. Overall, histopathological examination proved useful in 49% of cases, regardless of the organs sampled. It provided crucial diagnostic information in 18% of cases, characterized lesions in 20%, and revealed pre-existing medical conditions potentially contributing to death in 10% of cases.

Discussion : In most cases where heart and brain sampling provided forensically relevant information, it's likely that a thorough macroscopic examination and targeted sampling scheme would have led to the same conclusions. Notably, in 51% of cases, pathological analysis did not provide additional insights beyond macroscopic findings, raising questions about the necessity of systematic sampling. We propose a standardized sampling protocol that balances the quality of forensic investigations with practical constraints.

Key words: Forensic medicine – Forensic autopsy – Forensic Pathology – Organ retention – Autopsy practices – Death investigation

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Serment d'Hippocrate

En présence des enseignants et enseignantes
de cette Faculté,
de mes chers condisciples
et selon la tradition d'Hippocrate,
je promets et je jure d'être fidèle aux lois de l'honneur
et de la probité dans l'exercice de la Médecine.

Je donnerai mes soins gratuits aux indigents,
et n'exigerai jamais un salaire au-dessus de mon travail.

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les secrets qui me seront confiés et mon état ne servira pas
à corrompre les mœurs ni à favoriser le crime.

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je rendrai à leurs enfants
l'instruction que j'ai reçue de leurs parents.

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si je suis fidèle à mes promesses.
Que je sois couverte d'opprobre
et méprisée de mes confrères et consœurs
si j'y manque.

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Liste des abréviations

AFE : Amniotic Fluid Embolism

CA : Correspondence Analysis

CVA : Cerebrovascular Accident

DCM : Dilated Cardiomyopathy

EBV : Epstein-Barr Virus

HCM : Hypertrophic Cardiomyopathy

IML : Institut médico-légal

MI : Myocardial Infarct

MS : Multiple Sclerosis

SEM-EDX : Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy

SIDS : Sudden Infant Death Syndrome

SUDEP : Sudden Unexpected Death in Epilepsy

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Résumé en français

Introduction

Les autopsies médico-légales impliquent généralement un échantillonnage de certains organes pour un éventuel examen histologique. Des études ont montré que l'histologie systématique peut contribuer aux conclusions médico-légales dans jusqu'à 60% des cas.

Les recommandations européennes de 1999 suggèrent un échantillonnage de base des principaux organes, sans spécifier la taille des prélèvements ni la procédure exacte à suivre. Le médecin légiste prélève donc les organes (en entier ou des fragments) qui lui paraissent pertinents mais la décision de leur analyse revient au magistrat responsable de l'enquête.

Les organes prélevés ne sont pas restitués aux proches après les analyses anatomopathologiques et sont donc détruits. Toutefois, des familles ont fait part de leur volonté de récupérer ces prélèvements afin de les inhumer avec le défunt, particulièrement lorsqu'il s'agit du cœur ou du cerveau, souvent prélevés en entier. En ce sens, une nouvelle loi est en cours d'étude pour permettre aux familles de récupérer, s'ils le souhaitent, les échantillons effectués.

Dans ce contexte, nous avons mené une étude dont l'objectif était de déterminer quels organes prélevés pour analyse anatomopathologique avaient un impact sur la conclusion médico-légale, et plus particulièrement, s'il y avait un intérêt à prélever le cœur et le cerveau en entier.

Matériel et méthodes

Nous avons mené une étude sur les comptes rendus d'autopsie et d'analyse anatomopathologique des corps autopsiés à l'Institut Médico-Légal (IML) de Tours entre 2020 et 2022. L'utilité des prélèvements systématiques d'organes lors d'autopsies médico-légales a été évaluée, en classant les conclusions médico-légales en 7 catégories : 4 dites « utiles » (diagnostic, discordante, caractéristique lésionnelle, état antérieur) et 3 « inutiles » (confirme, non contributif, lésions mineures).

Résultats

Sur 1068 autopsies réalisées entre 2020 et 2022 à l'IML de Tours, des prélèvements systématiques ont été faits dans 99% des autopsies. Néanmoins, l'analyse histologique n'a été ordonnée par le magistrat que dans 21% des cas.

Sur les 142 dossiers analysés, les organes les plus prélevés étaient les poumons (98%), le foie (94%), le cœur en entier (94%), les reins (87%), le larynx (87%) et le cerveau en entier (86%).
La réalisation de l'examen histopathologique s'est avérée globalement utile dans 49 % des cas, peu importe les organes prélevés, fournissant la cause du décès dans 15% des cas, réfutant des causes de décès dans 3% des cas, caractérisant des lésions traumatiques dans 20 % des cas et révélant des conditions médicales préexistantes ayant pu participer au décès dans 10 % des cas.

Par ailleurs, l'analyse anatomopathologique du cœur et du cerveau a permis la catégorisation des conclusions médico-légales dans une des catégories dites « utiles » dans 44 % des cas pour le cœur et dans seulement 14 % des cas pour le cerveau.

Discussion

Nos résultats soulèvent d'importantes questions sur les pratiques actuelles de l'IML de Tours, notamment en termes d'utilité de l'échantillonnage systématique dans le contexte médico-légal.

Analysé dans 1 cas sur 5 et « utile » dans seulement 1 cas sur 2, le prélèvement systématique d'organes (en entier ou des fragments) apparaît peu pertinent. Dans 34% des cas, l'histologie a été utilisée uniquement pour confirmer des observations macroscopiques faites durant l'autopsie. Bien que compréhensible pour les jeunes praticiens, les médecins plus expérimentés devraient davantage se fier à leur jugement.

Concernant le cœur prélevé en entier, la plupart des diagnostics réalisés étaient des infarctus du myocarde, des myocardites et des types de cardiomyopathies. Il est probable que dans la majorité des cas, un examen macroscopique rigoureux associé à un échantillonnage ciblé aurait conduit aux mêmes conclusions.

De même, parmi les éléments d'intérêt médico-légaux apportés par le prélèvement du cerveau en entier, notamment dans les cas de traumatismes crâniens, il est probable que la réalisation d'un scanner post-mortem en complément de l'autopsie aurait fourni suffisamment d'informations pour ne prélever que des échantillons de tissu cérébral.

Face à une pénurie d'experts anatomopathologistes, à des ressources financières limitées, des difficultés de stockage et à l'impact émotionnel que peut avoir le prélèvement systématique d'organes hautement symboliques pour les proches du défunt, une approche plus ciblée et réfléchie dans les pratiques d'échantillonnage et de recommandations de l'analyse histologique s'avère nécessaire. Cette approche plus sélective permettrait non seulement d'optimiser l'utilisation de nos ressources, mais aussi d'assurer que chaque analyse histologique s'inscrit dans une démarche médicale.

Ainsi, nous proposons un protocole standardisé visant à équilibrer la qualité des enquêtes médico-légales avec les contraintes pratiques actuelles.

Introduction

When performing a medico-legal autopsy, it is customary to sample major organs to complete post-mortem investigation with a histological examination. Thanks to various studies from the past 20 years (1–7), we know systematic histology can contribute to post-mortem findings and assist forensic investigations (up to 60% of cases in some studies (2,3)), provided that sufficient sampling has been taken.

Recommendations were made in 1999 by the Committee of Ministers of the European council advocating harmonization of forensic practices throughout Europe. They stipulate: "*scope of the sampling procedure is to be case-dependent. However (…) in all autopsies, the basic sampling scheme includes specimens from the main organs for histology*" (8). This document is frequently cited and used as a reference in a number of textbooks and national guidelines including the French guidelines (9–13); however, it doesn't specify either size of sampling or sampling procedure, leaving those at the discretion of the forensic doctor. According to *Knight's Forensic Pathology (fourth ed.)* (12), at a minimum, samples of brain, heart, lung, liver, kidney, pancreas, spleen, thyroid, adrenals and muscle should be retained.

Specialized pathologists have made further recommendations for some organs. This is particularly the case for the heart (14–16) and the brain (17–19). In cases of sudden unexplained death or suspected cardiac pathology, best practice is to retain the whole organ after thorough gross examination. As for the brain, neuropathologists advocate fixing the uncut brain *in toto* to provide high quality macroscopic as well as microscopic examination (9,20), especially when pre-existing brain condition is known or in head trauma cases.

In France, the person conducting the forensic autopsy is not the same as the one who performs the histological analysis. The former is a forensic doctor with limited experience in pathology, while the latter is a pathologist who has received additional training in forensic medicine. These specialized pathologists are few in number across the country, and their work incurs an additional cost to the judiciary system (21). Consequently, at the end of every autopsy, forensic practitioners verbally communicate their initial conclusions to the Public Prosecutor's Office and recommend, or not, a histological examination. Generally, histology is advised for several reasons: when the cause and manner of death remain unknown, to confirm findings observed during the autopsy, or to characterize and date traumatic injuries (1,6,22). Prosecutors choose to proceed with the analysis or to destroy the collected tissues. Pending their decision, samples are placed under seal and retained at the Medico-legal Institute.

Judicial autopsies are ordered by the authorities without consulting the wishes of deceased or their relatives. Additionally, it is rarely communicated to families that specimens are systematically taken during an autopsy for ancillary tests. Furthermore, whether small samplings or entire organs, their disposal as biological hazard products after histological analysis are ethically questionable for the bereaved. This overall lack of communication, combined with the destruction of sometimes highly symbolic organs, such as the brain and the heart, has led to several public controversies, which, in turn, have prompted new reforms. A prime example is the Alder Hey Affair in the UK in 1999, which led to the Human Tissue Act of 2004 (23–25).

More recently, in France, the 2016 Nice truck attack raised similar concerns among the public. From the 86 casualties, 14 underwent an autopsy, including the perpetrator of the attack (26). Extensive sampling and organ retention took place during those autopsies, a practice that was judged as unjustified by the press and bereaved families (27–29). As a result, a new law is currently being studied to improve communication about human tissue retention and to allow families to recover specimens taken during autopsy for further funeral arrangements (30).

Even though general European recommendations exist, no clear protocol has been made in France regarding the specifics of tissue sampling. Left to the discretion of the forensic doctor performing the autopsy, medico-legal practice in our country suffers from a lack of consistency. In addition to the concerns from past years, it is legitimate to question the usefulness of systematic sampling, especially whole organ retention.

In this context, we conducted a retrospective study using autopsy and pathology reports from the Medico-legal Institute of the University Hospital of Tours to determine whether the choice of organs sampled, impacted forensic conclusions. And more specifically, if systematic sampling of the heart and the brain were necessary to establish the truth. In cases where it was, we then assessed whether the whole organ was required or if a smaller sample would have sufficed to conclude the investigation.

Materials and Methods

We retrospectively reviewed all autopsy files from January 1, 2020, to December 31, 2022, at the Medico-legal Institute of Tours. We included all autopsies for which a histological examination was ordered by the Prosecutor's Office and for which a pathological report was found in our archives. It's important to note that at the time of this study, there was no local protocol detailing organ sampling procedures at the Medico-legal Institute of Tours. Thus, sampling practices could vary among forensic doctors.

Cases involving children under 2 years were excluded, as clear recommendations for histological sampling already exist concerning post-mortem exams for sudden infant death syndrome (SIDS) (31,32). Additionally, another case was excluded from our study due to its complexity, which resulted in 3 contradictory histological conclusions. Indeed, samplings were analyzed 3 times by three different pathologists which resulted in a different conclusion each time.

Autopsy data collection

From computerized files and paper archives, the following data was obtained for each case: sex, age, gross findings observed during the autopsy, supposed cause and manner of death at the end of autopsy, fate of the toxicological seal (destroyed, analyzed, retained), whether toxicology was ordered before or at the same time as histology.

Post-autopsy data collection

When pathology files were available, the following data was recorded: list of sampled organs, whether whole organs or samples were retained, the main organ in which a fatal pathology was found and any discrepancies between gross and microscopic examinations.

The final cause and manner of death were established based on the synthesis of each file. Only histology was considered for this determination, even if toxicology analysis was performed. This approach was chosen to evaluate the specific impact of histopathology on determining the cause of death, and due to inconsistent access to complete toxicology reports. While we acknowledge that toxicology could provide valuable additional information, our aim was to assess the standalone contribution of histological examination in forensic autopsies.

Histology classification

We compared each autopsy report to its respective pathology report and classified the results into the following 7 categories:

- Diagnostic: Pathology was required to reach a diagnosis, and/or the cause and manner of death were determined only through histology.
- Confirmatory: The histological examination was consistent with the gross analysis or confirmed the cause and manner of death identified by the forensic doctor during the autopsy.
- Discordant: The findings or suspicions from the autopsy were contradicted by histology.

- Non-Contributory: Microscopic examination was inconclusive or deemed unnecessary by the pathologist; the cause and manner of death remain undetermined.
- Injury Characteristics: Histology was performed to assess ante- and post-mortem injuries, estimate wound age, or confirm entry and exit wounds in ballistic cases.
- Prior Condition: The pathological exam revealed a pre-existing health condition that could have contributed to the cause or manner of death, and which had not been seen during autopsy.
- Minor Lesions: The microscopic examination identified a pre-existing condition or lesion that did not contribute to the cause or manner of death.

We designed this 7-category classification system based on our experience in terms of possible pathology outcomes. This classification covers the full spectrum of possible outcomes from histological examinations. It ensured that every result can be categorized, facilitating statistical analysis and providing a tool to nuance how histology contributed to the autopsy findings.

First, we categorized the results to assess the overall usefulness of pathology performance in each case. We then classified heart and brain specimens using the same categories. Overall, histological examination was considered useful if classified in the following categories: diagnostic, discordant, injury characteristics and prior condition. It was deemed unnecessary or redundant if classified in categories: confirmatory, non-contributory and minor lesions.

Statistical Analysis

A descriptive analysis was performed using *pvalue.io, a graphic user interface to the R statistical analysis software for scientific medical publications (2019-24)*. Qualitative variables were presented as counts and percentages. Due to the sample size not meeting minimum requirements to perform an independent chi-square test, Fisher's exact test was applied to assess associations between our qualitative variables.

For all statistical tests, the significance level was set at 5% ($p<0.05$). When significant results were revealed, post-hoc analysis was performed using Dunn's test to identify specific group differences.

Additionally, a correspondence analysis (CA) was performed using the XLSTAT package software. CA is a statistical technique that helps visualize and interpret complex data, especially when dealing with qualitative variables. The resulting plot permitted the observation of relationships among sampled organs and histology classification.

Results

From a total of 1,068 forensic autopsies performed between January 1, 2020, and December 31, 2022, systematic sampling took place in 1,056 cases (99%). After reporting to the Prosecutor's Office, samples were destroyed in 438 cases (41%), a histological exam was ordered for 225 cases (21%), and in 393 cases (37%), specimens are still retained in our Medico-legal Institute, awaiting a judicial decision. Pathologists written reports were found in our archives for 158 cases (70%). Fifteen cases involving children under 2 years old were excluded from our study, as well as a complex case that led to three contradictory conclusions. Therefore, 142 autopsies were analyzed (13%) out of the 1,068 autopsies performed in three years, as shown in **Figure 1**, which represents the flowchart of this study.

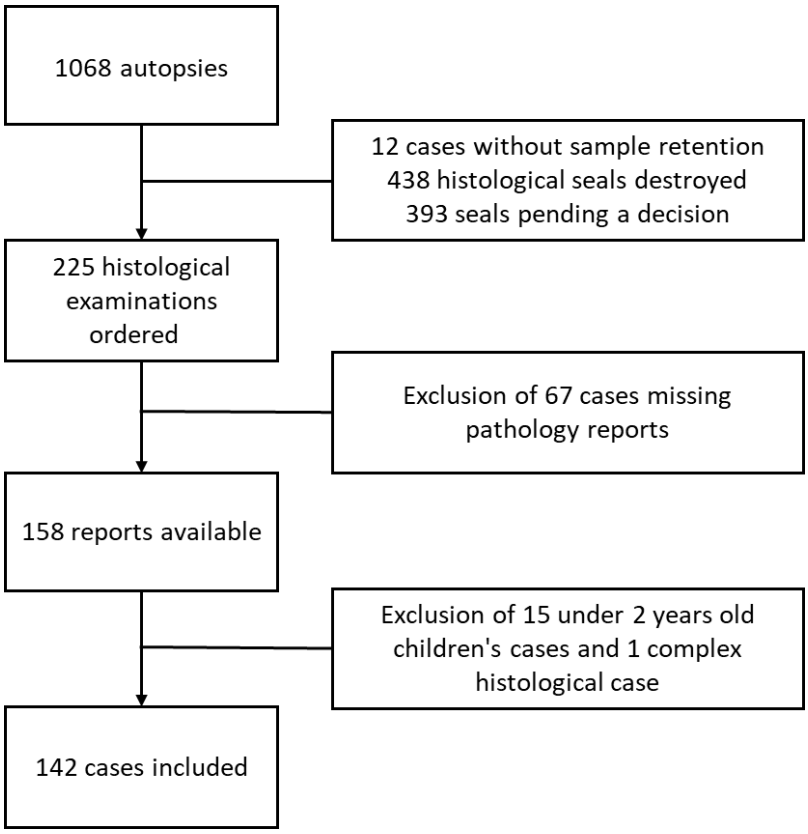

Figure 1: Study flowchart

Autopsy data

The sex ratio was 1,84:1, with 92 males and 50 females. The mean and median age was 50 years, ranging from 5 to 91.

The majority of cases reviewed were determined deaths, meaning 21 homicides (15%), 9 suicides (6%), 21 accidental deaths (15%) and 33 natural deaths (26%). In 58 cases (41%), manner of death was undetermined following autopsy. All these results are summarized in **Table 1.**

Table 1: Summary of Manner of Death Distribution after autopsy

Manner of death	No. of cases	% of cases
Homicide	21	15
Suicide	9	6
Accidental	21	15
Natural	33	23
Undetermined	58	41
Total	142	100

Toxicology was performed in 111 (78%) of the included cases. It was ordered at the same time as histological analysis by the Prosecutor's Office in 79 cases (71%). Toxicology was done first in 31 cases (28%). In only 1 case (0,9%) was pathology requested to be done first.

Post-autopsy data

Lung tissue was the most commonly organ sampled, present in 139 cases (98%). The liver and whole heart were the next most frequent, each sampled in 134 and 133 cases respectively (94%). Kidneys were sampled in 124 instances (87%) and larynx in 123 (87%). The whole brain was retained in 122 cases (86%). Spleen samples were taken in 85 cases (60%), while the pancreas was sampled in 63 cases (44%). Adrenal glands were collected in 55 cases (39%). Injury-related samples (including skin, bones, hematomas) were taken in 54 cases (38%). Both the stomach and reproductive system were sampled in 29 and 28 instances respectively (20%). Brain samples, as opposed to whole brain retention, were taken in only 13 cases (9%), while heart samples were the least common, collected in just 5 cases (4%). **Table 2** summarizes those results.

Table 2: Listing of organs sampled

Tissue	No. of cases	% of cases
Lung	139	98
Liver	134	94
Whole heart	133	94
Kidneys	124	87
Larynx	123	87
Whole brain	122	86
Spleen	85	60
Pancreas	63	44
Adrenals	55	39
Injury	54	38
Stomach	29	20
Reproductive system	28	20
Brain sample	13	9
Heart sample	5	4

More specifically, from the total of 142 autopsies, brain was retained whole in 122 cases (86%), sampled in 13 cases (9%) and absent from pathology seal in 7 cases (5%). As for the heart, it was examined whole by pathologists in 133 cases (94%), sampled in 5 cases (3%) and absent in 4 (3%). These results are shown in **Figure 2 and 3**.

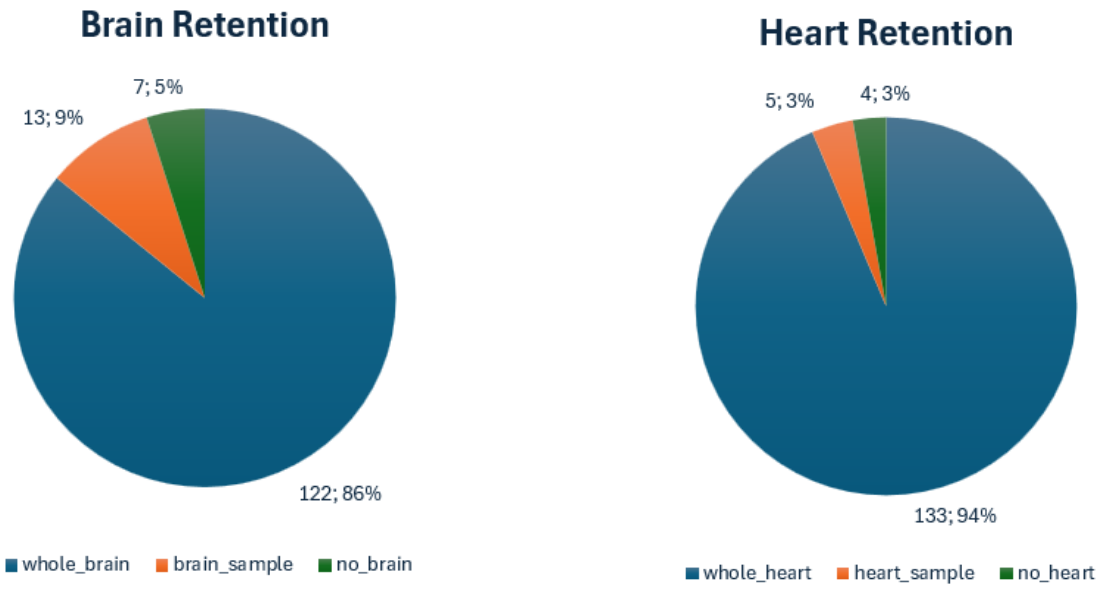

Figure 2 and 3: Brain and heart retention

Histology classification

Overall classification

Pathology was essential to reach a diagnosis in 22 cases (15%). Histology confirmed findings already observed during gross examination in 48 cases (34%). It disproved 4 suspected causes of death (3%). Additionally, injuries were further characterized in 29 cases (20%), and a pre-existing health condition that could have contributed to the cause of death was revealed in 14 cases (10%). Histology identified a minor lesion that did not contribute to the mechanism of death in 4 cases (3%). Pathology analysis was inconclusive in 21 cases (15%).
Classification distribution is resumed in **Figure 4**.

We investigated associations between pathology classifications and various organ samples using Fisher's test followed by Dunn's test. A significant association was found between the presence of injury samples and the pathologist's ability to further characterize injuries ($p<0.001$). There was also an association ($p=0.021$) between reproductive system sampling and the minor lesions categorization. However, no statistically significant associations were found between pathology classifications and most other organs, including the heart and the brain. All results are summarized in **Table 3**.

Table 3: Univariable analysis.

		Classification diagnostic (n = 21)	Classification confirmatory (n = 48)	Classification discordant (n = 5)	Classification non_contributory (n = 21)	Classification injury_characteri... (n = 29)	Classification prior_condition (n = 14)	Classification minor_lesions (n = 4)	n	p	test
Adrenals	yes	7 (33%)	18 (38%)	1 (20%)	7 (33%)	15 (52%)	3 (21%)	4 (100%)	55	0.087	Fisher
	no	14 (67%)	30 (62%)	4 (80%)	14 (67%)	14 (48%)	11 (79%)	0 (0%)	87	-	-
Brain sample	yes	0 (0%)	8 (17%)	0 (0%)	3 (14%)	1 (3.4%)	1 (7.1%)	0 (0%)	13	0.28	Fisher
	no	21 (100%)	40 (83%)	5 (100%)	18 (86%)	28 (97%)	13 (93%)	4 (100%)	129	-	-
Injury	yes	5 (24%)	14 (29%)	1 (20%)	4 (19%)	27 (93%)	2 (14%)	1 (25%)	54	**<0.001**	Fisher
	no	16 (76%)	34 (71%)	4 (80%)	17 (81%)	2 (6.9%)	12 (86%)	3 (75%)	88	-	-
Kidneys	yes	19 (90%)	39 (81%)	5 (100%)	20 (95%)	24 (83%)	13 (93%)	4 (100%)	124	0.71	Fisher
	no	2 (9,5%)	9 (19%)	0 (0%)	1 (4.8%)	5 (17%)	1 (7.1%)	0 (0%)	18	-	-
Larynx	yes	20 (95%)	39 (81%)	5 (100%)	18 (86%)	24 (83%)	14 (100%)	4 (100%)	124	0.47	Fisher
	no	1 (4,8%)	9 (19%)	0 (0%)	3 (14%)	5 (17%)	0 (0%)	0 (0%)	18	-	-
Liver	yes	20 (95%)	47 (98%)	5 (100%)	18 (86%)	26 (90%)	14 (100%)	4 (100%)	134	0.37	Fisher
	no	1 (4,8%)	1 (2.1%)	0 (0%)	3 (14%)	3 (10%)	0 (0%)	0 (0%)	8	-	-
Lungs	yes	21 (100%)	47 (98%)	5 (100%)	21 (100%)	27 (93%)	14 (100%)	4 (100%)	139	0.66	Fisher
	no	0 (0%)	1 (2.1%)	0 (0%)	0 (0%)	2 (6.9%)	0 (0%)	0 (0%)	3	-	-
Pancreas	yes	9 (43%)	19 (40%)	2 (40%)	9 (43%)	15 (52%)	5 (36%)	4 (100%)	63	0.39	Fisher
	no	12 (57%)	29 (60%)	3 (60%)	12 (57%)	14 (48%)	9 (64%)	0 (0%)	79	-	-
Reprod system	yes	5 (24%)	9 (19%)	0 (0%)	7 (33%)	4 (14%)	0 (0%)	3 (75%)	28	**0.022**	Fisher
	no	16 (76%)	39 (81%)	5 (100%)	14 (67%)	25 (86%)	14 (100%)	1 (25%)	114	-	-
Heart sample	yes	0 (0%)	4 (8.3%)	0 (0%)	1 (4.8%)	0 (0%)	0 (0%)	0 (0%)	5	0.53	Fisher
	no	21 (100%)	44 (92%)	5 (100%)	20 (95%)	29 (100%)	14 (100%)	4 (100%)	137	-	-
Spleen	yes	12 (57%)	23 (48%)	3 (60%)	12 (57%)	21 (72%)	10 (71%)	4 (100%)	85	0.23	Fisher
	no	9 (43%)	25 (52%)	2 (40%)	9 (43%)	8 (28%)	4 (29%)	0 (0%)	57	-	-
Stomach	yes	4 (19%)	9 (19%)	1 (20%)	3 (14%)	7 (24%)	3 (21%)	2 (50%)	29	0.79	Fisher
	no	17 (81%)	39 (81%)	4 (80%)	18 (86%)	22 (76%)	11 (79%)	2 (50%)	113	-	-
Whole brain	yes	21 (100%)	37 (77%)	5 (100%)	16 (76%)	26 (90%)	13 (93%)	4 (100%)	122	0.12	Fisher
	no	0 (0%)	11 (23%)	0 (0%)	5 (24%)	3 (10%)	1 (7.1%)	0 (0%)	20	-	-
Whole heart	yes	21 (100%)	43 (90%)	5 (100%)	20 (95%)	27 (93%)	14 (100%)	4 (100%)	134	0.76	Fisher
	no	0 (0%)	5 (10%)	0 (0%)	1 (4.8%)	2 (6.9%)	0 (0%)	0 (0%)	8	-	-

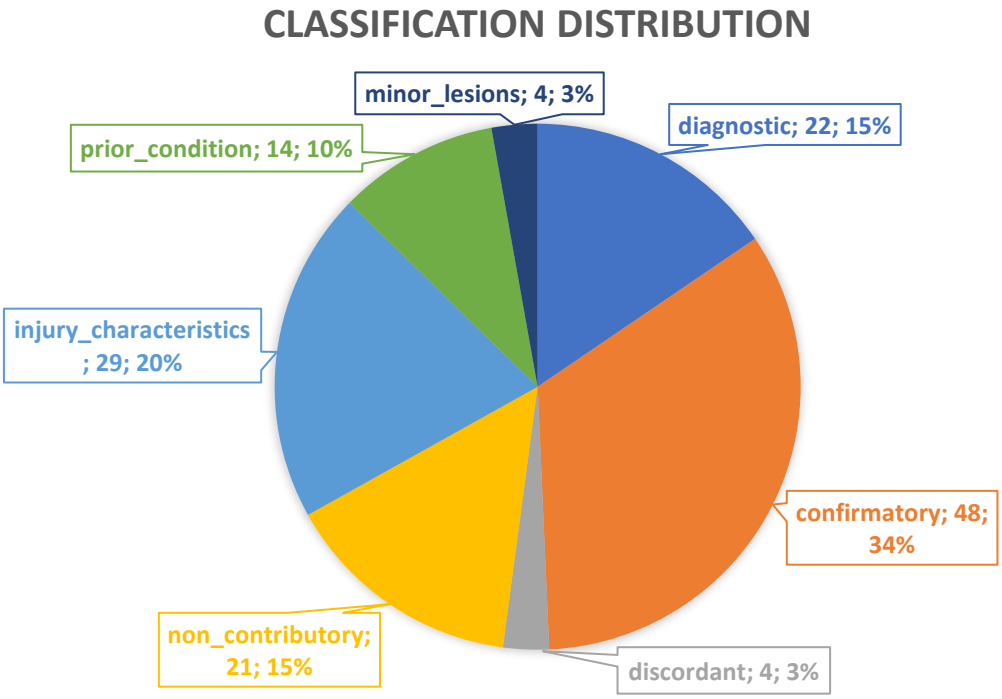

Figure 4: Classification distribution

We have seen that 22 diagnoses (15% of total cases) were made only through the performance of pathology analysis. The heart was the most frequently diagnostic organ, with 13 cases total: 6 cases of myocarditis, 5 cases of acute myocardial infarction (MI), 1 case of severe amyloidosis, and 1 case of dilated cardiomyopathy (DCM) with mitral valve prolapse in a maternal death. In 4 instances, diagnosis was made from lung sample: 2 cases of severe pneumopathy, 1 case of pulmonary embolism, and 1 case of amniotic fluid embolism (AFE). Brain disorders were represented by 2 cases: 1 brainstem localized multiple sclerosis (MS) lesion and 1 head trauma which was unseen at gross examination. The remaining cases included 1 pancreatic adenocarcinoma, 1 thyroid bone fracture, and 1 spinal subdural hematoma. Notably, all of these diagnoses were made in cases where whole brain and whole heart were retained. All diagnoses are listed in **Table 4**.

Table 4: Listing of diagnoses found solely by pathology examination

Main organ	Diagnosis	No. of cases
Heart	Myocarditis	6
	Acute myocardial infarction	5
	Sever amyloidosis	1
	DCM + Mitral valve prolapse	1
Lungs	Sever pneumopathy	2
	Pulmonary embolism	1
	Amniotic fluid embolism	1
Brain	Brainstem localized MS lesion	1
	Head trauma	1
Pancreas	Adenocarcinoma	1
Larynx	Thyroid bone fracture	1
Spine	Subdural hematoma	1

In 48 cases (34%), the cause of death was found at autopsy and confirmed by pathology. The main organs concerned were the heart (13 cases), lungs (13 cases), and brain (11 cases). Diagnoses found in the heart were: 8 acute MIs, 2 severe hypertrophic cardiomyopathies (HCM), one myocarditis, one aortic dissection and, one case where a cardiac defibrillator showed arrhythmia. In the lungs, severe pulmonary edema of unknown origin was confirmed in 4 cases, overinflated lungs (also called "*emphysema aquosum*") was present in 3 drowning cases, massive gastric content inhalation was confirmed in 2 cases as well as 2 cases of severe emphysema, one case of pulmonary embolism and one sever pneumonia. In 3 cases of sudden unexpected death in epilepsy patients (SUDEP), gross autopsy found common and non-specific findings of an epileptic seizure such as signs of asphyxia, tongue biting, congestion and brain edema which was confirmed by histology. In 3 cases, whole brain was used to confirm the presence of cerebrovascular accidents (CVAs). Organs from the digestive system permitted pathologist to confirm gross findings in 5 cases: perforated ulcer, ruptured spleen from an Epstein Barr Virus (EBV) infection, acute pancreatitis, kidney cancer, liver cancer. A number of traumas (5 accidental head injuries and 6 cases of multiple traumatic injuries) are included in this category, confirming gross findings through histology without being the object of further characterization by the pathologist. These diagnoses are listed in **Table 5**.

Table 5: Listing of diagnoses that were found at autopsy and confirmed by pathology

Main organ	Diagnosis	No. of cases
Heart	Acute MI	8
	HCM	2
	Myocarditis	1
	Arrythmia	1
	Aortic dissection	1
Lungs	Acute pulmonary edema	4
	Drowning	3
	Inhalation pneumonia	2
	Emphysema	2
	Pulmonary Embolism	1
	Sever pneumonia	1
Brain	Head Trauma	5
	Cerebrovascular Accident	3
	SUDEP	3
Injury	Multiple trauma	6
Stomach	Perforated ulcer	1
Spleen	EBV infection	1
Pancreas	Acute pancreatitis	1
Kidney	Adenocarcinoma	1
Liver	Tumor	1

Histology disproved 4 major hypotheses made during autopsy. Interestingly, once again, they concerned the brain (2 cases), heart (1 case), and lungs (1 case). In 2 cases, forensic doctors stipulated the cause of death to be CVAs when one was actually a head trauma, and another didn't have any brain abnormalities. In one case, the cause of death was thought to be linked to a hypertrophic cardiomyopathy (HCM); however, microscopic examination disproved this hypothesis. Finally, a thrombus in the lungs was initially concluded to be a pulmonary embolism when in reality, it was a post-mortem thrombus. Details of these 4 cases are summarized in **Table 6**.

Table 6: Listing of disproven gross diagnosis

Supposed Cause of Death	Histology findings	Cause of death after pathology
Cerebrovascular Accident	« Coup - contre coup » head trauma	Sever head trauma
Cerebrovascular Accident	Normal brain examination	Sever acute pulmonary edema
HCM	Regular myocardium	Undetermined
Pulmonary Embolism	Post Mortem Thrombus	Undetermined

In 21 cases (15%), histology didn't provide any additional information. It concerned 21 undetermined deaths including 3 putrefied bodies (out of the 3 putrefied cases present in our study).

Histology further characterized injuries in 29 cases (20%). Notably, most of these concerned homicides (19 cases), followed by undetermined deaths (5 cases) and suicides (3 cases). Most of those observations were done on whole brain (14 cases of head trauma), whole heart (2 cases), targeted skin and bone samples. In 13 cases, histology provided an estimation of wound age. In 5 cases, it permitted the establishment of a chronology of different traumatic events. In 3 cases, it was useful in differentiating between pre-mortem and post-mortem wounds. In 2 cases, the pathologist was able to estimate survival time. Additionally, in 4 cases, pathologists used Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX). This is a specialized technique used to detect gunshot residue and search for traces of metals that could characterize agents used to inflict injuries.

A prior health condition was found in 14 cases which could have participated in or contributed to the cause of death, pending toxicology or genetic results. This concerned 9 undetermined death cases, 2 natural deaths, and 2 accidental deaths. Diagnoses were mostly cardiomyopathies: 6 HCM, 3 coronary stenoses less than 70%, 1 valvular disease, 1 suspected Brugada syndrome, and 1 amyloidosis. In 2 cases, advanced cirrhosis was present in accidental deaths with multiple traumatic injuries.

In 4 cases, histology was only useful to show the presence of minor lesions which had not been seen during autopsy, but which did not participate in the mechanism of death. Those were: a case of advanced cirrhosis in a non-traumatic death, a chronic bronchitis, an ovarian cyst and a grade 1 meningioma.

In total, pathology contributed significantly to the understanding of the mechanism of death in nearly half of the cases (49%), providing additional insights beyond those observed during the autopsy. However, in 51% of cases, it either confirmed a diagnosis made by the forensic doctor, did not provide any new information, or found a minor lesion that was not relevant to the case.

Brain classification

We compared gross examination of the brain made during autopsy to its matching pathology report to classify more specifically brain tissue retention to the seven categories previously used. Results are shown in **figure 5**.

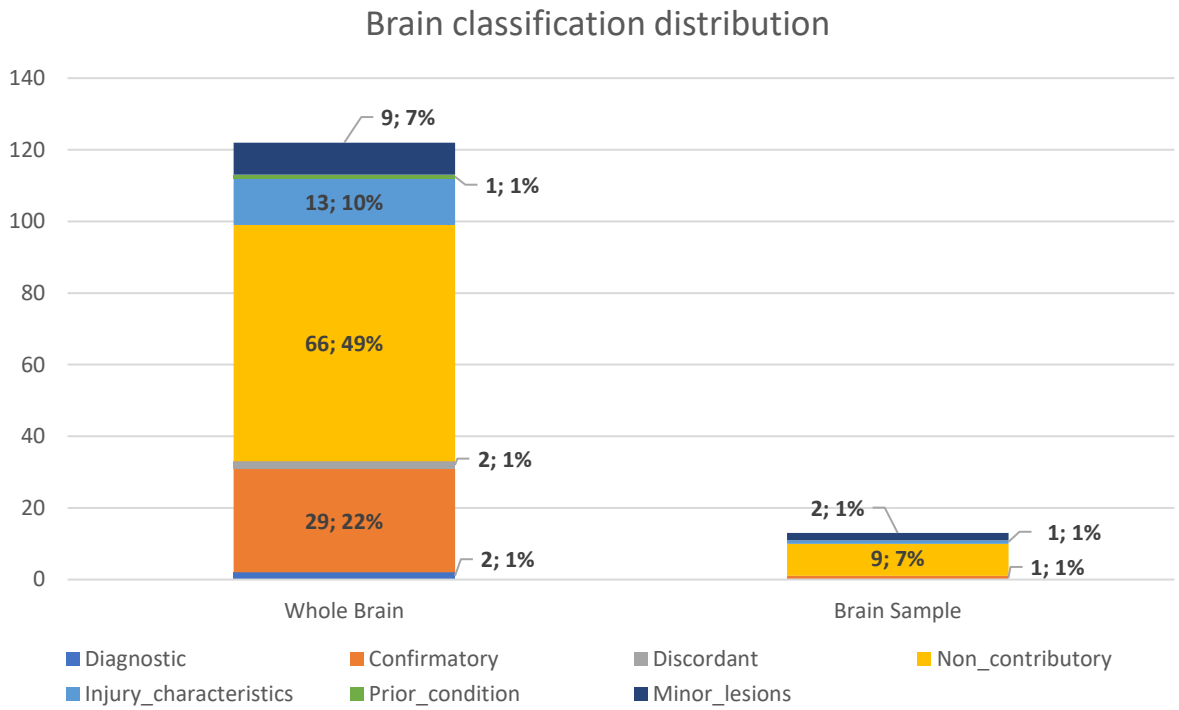

Figure 5: whole brain and brain sample classification distribution

Overall, whether sampled or retained whole, histological examination of the brain was only useful in 14% of our cases. It provided diagnostic insights in 2 cases (1%): one case of multiple sclerosis (MS) lesion localized in the brainstem and one head trauma that was unseen at autopsy. It disproved 2 cases (1%) thought to be CVAs. It aided in further characterization of head traumas in 14 cases (11%). In one case (1%), narrowing of a cerebral artery which could have participated in the mechanism of death was found by the pathologist.

Notably, in 104 cases (86%), histology of the brain was mostly non-contributory (56%), confirmatory (23%) or revealed minor lesions which did not contribute to the mechanism of death (8%). Minor lesions were mostly seen in elderly patients with cerebral atrophy and neuro-degenerative diseases such as Alzheimer's.

When only sampled (13 cases), brain tissue was non-contributory, confirmed gross examination assessment or showed minor lesions that did not affect the cause or mechanism of death. In only one case (1%), sampled brain tissue permitted further characterization of an accidental head trauma.

Fisher's test didn't show any significance between brain distribution across the seven different categories (p=0.212).

Heart classification

As done for the brain, we then concentrated on classifying heart retention into our seven groups (**figure 6**).

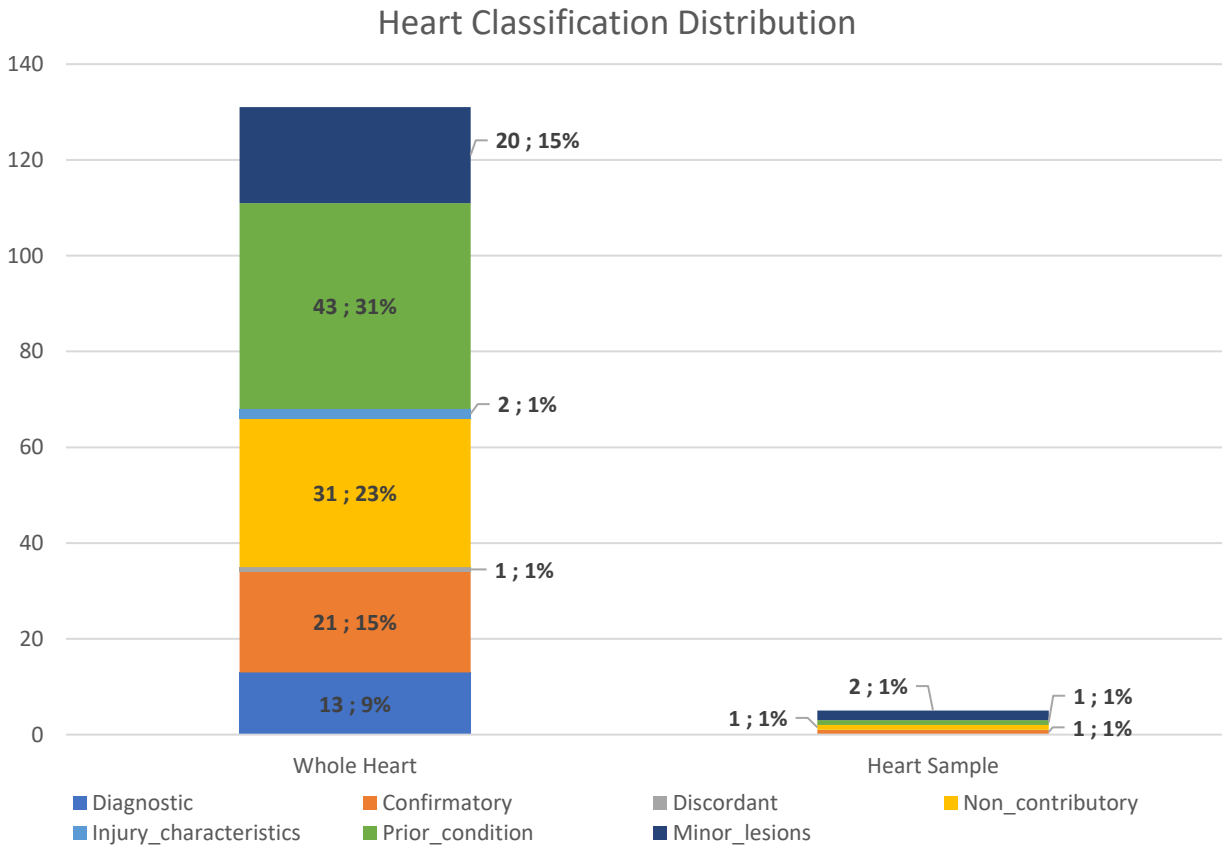

Figure 6: whole heart and heart sample classification distribution

Histological examination of heart tissue, whether whole or sampled, proved useful in 44% of our cases. It provided diagnostic insights in 13 cases (9%), which are listed in **Table 4**. It aided in characterizing heart injuries in 2 homicides (1%) and disproved the initial gross examination assessment in 1 case (1%). In 44 cases (32%), it revealed a prior health condition that could have contributed to the mechanism of death pending toxicology and genetic results.

The majority of these useful findings came from whole heart examinations. Heart samples contributed to only 1 case (1%), identifying a prior condition of hypertrophic cardiomyopathy.

In 22 cases (16%), pathology confirmed gross findings such as acute infarct, coronary artery narrowing, and myocarditis seen by forensic doctor. And in another 22 cases (16%), histology revealed minor lesions that didn't constitute a prior health condition.

Fisher's test didn't show any significance between heart distribution across the seven different categories (p=0,687).

Concerning cause and manner of death after pathology

Out of 142 reviewed files, the cause of death was provided or modified in 26 cases (18%) through histological examination (22 provided and 4 modified). Pathology in the cardiac system accounted for most of the diagnoses (13 provided, 1 modified), followed by the lungs (4 provided, 1 modified) and the brain (2 provided, 2 modified). The pancreas, larynx, and spine each provided a cause of death.

Histological findings also led to changes in the determination of the manner of death. Of the 58 cases (41%) with an undetermined manner of death after gross autopsy, histology provided diagnoses in 13 cases (22%). Among the previously determined manners of death, 2 cases (one homicide and one accidental) were modified and reclassified as undetermined after further pathological analysis.

Thus, following pathology, the final manner of death distribution was as follows: 47 cases remained undetermined (33%), 20 homicides (14%), 9 suicides (6%), 20 accidental deaths (14%), and 46 natural deaths (32%).

Correspondence Analysis

Our study contains mainly qualitative variables: presence of different organs and pathology classification results. To better visualize potential associations among those variables, a correspondence analysis was performed. It uses two dimensions that explain more than 90% of the variance of our dataset (Dimension 1: 68% and Dimension 2: 31%). Results of this analysis are depicted in **figure 7**.

This plot reveals multiple trends between several variables:

- The Diagnostic Cluster: A cluster of organs including whole brain, whole heart, larynx, kidney, liver, lungs, and spleen is positioned close to the diagnostic category. The prior condition category and discordant classification are also nearby. This proximity suggests that examinations of these organs are more likely to yield diagnostically useful results in pathology examinations.

- The Non-useful/Redundant Cluster: stomach, pancreas, and adrenals are situated near categories that are generally considered non-useful or redundant in pathological examinations. This positioning implies that these organs may less frequently provide unique or critical information during autopsies.

- The Isolated Samples: Heart and brain samples as well as reproductive system appear isolated on the plot, positioned far from any classification points. This isolation is likely attributable to their extremely small sample size, which sets them apart from other variables.

- The Injury Association: There is a clear proximity between injuries and the injury characterization group on the plot. It demonstrates that when injuries are present, they are indeed further characterized by the pathologist.

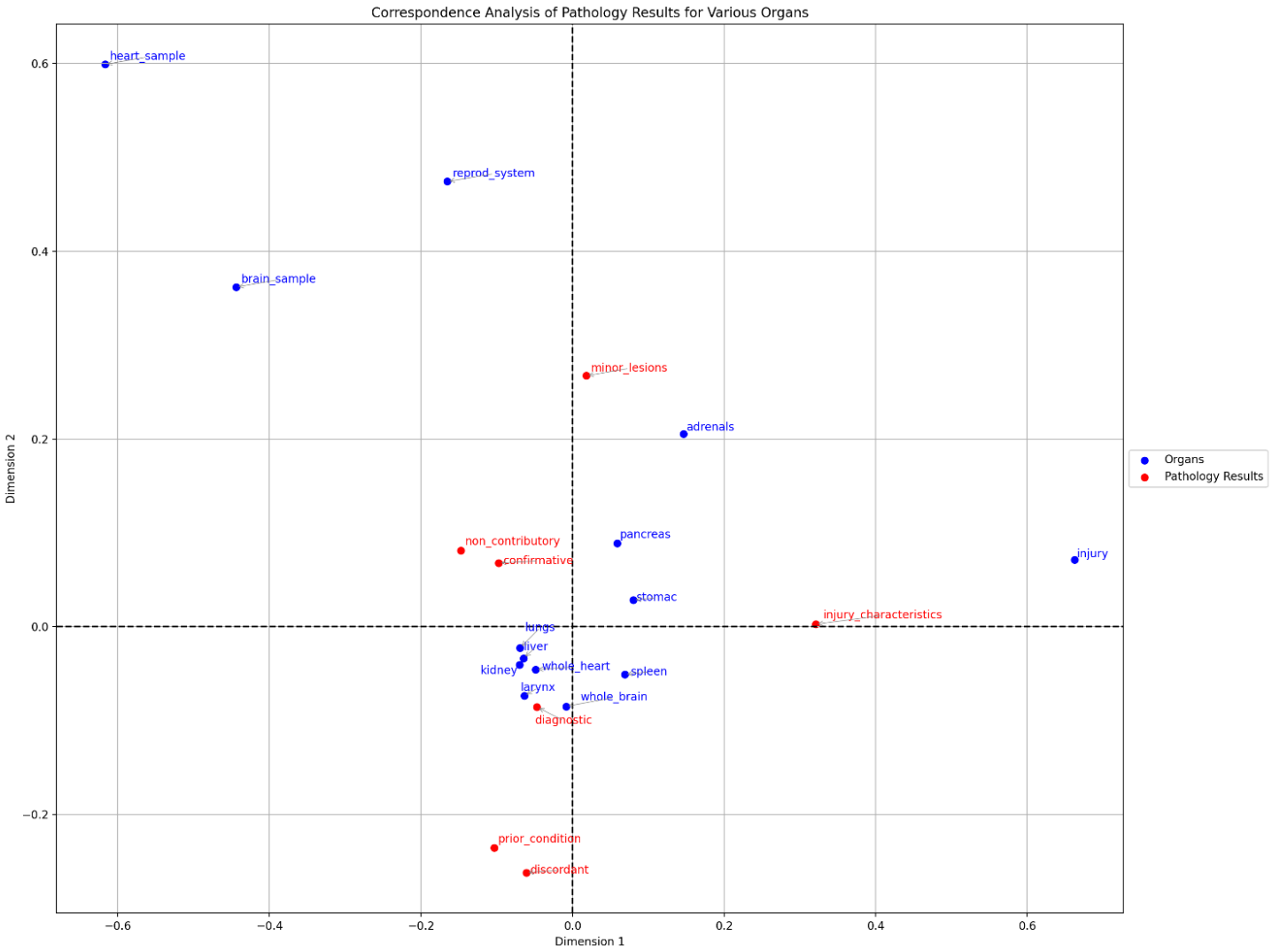

Figure 7. Correspondence Analysis Plot

This interpretation provides insights into the apparent relationships between different organs and pathology results, highlighting organs of diagnostic utility and potential areas of redundancy in the pathological examinations.

Discussion

Histological analysis is not always performed after a medico-legal autopsy in France. However, systematic sampling of major organs is conducted nearly every time in our forensic department even though no clear recommendations exist concerning this subject.

Impact of pathology

Autopsy practices at the Medico-legal Institute of Tours

In our forensic department, most autopsies (99%) were the object of systematic sampling. Organs most frequently retained included the lungs (98%), liver (94%), whole heart (94%), kidneys (87%), larynx (87%) and whole brain (86%).

From our data, several observations can be made about our practices:

- Despite systematic organ sampling, histological analysis was only requested in 21% of cases, and when performed, it yielded redundant or inconclusive results in 51% of these cases. This raises questions about the utility of systematic sampling but also about histological recommendations in forensic context.

- The routine retention of organs like the neck structures, stomach, spleen, pancreas, and adrenals often occurred without any gross abnormalities in our department, and histology was seldom performed on these organs by pathologists. This practice could be viewed as unnecessary and unjustified.

- The practice of systematically retaining whole organs such as the heart and brain also needs to be questioned. First, the heart provided additional information in 44% of cases, and the brain in only 14%. Second, this practice does not align with European recommendations, which advocate for selective sampling based on visual abnormalities or specific circumstances of death, rather than retaining whole organs as a routine procedure. This points to a need for re-evaluation of our department's practices.

- In several instances, significant gross diagnoses were identified by the pathologist but had been missed during the initial autopsy by the forensic doctor. This emphasizes the need for greater rigor in gross examinations. Improving training in this area could not only enhance diagnostic accuracy but also reduce reliance on histology.

- In 34% of cases, histology was used solely to confirm macroscopic findings observed during the autopsy. While it is understandable that junior practitioners might need histology to corroborate their observations, more experienced doctors should aim to trust their own gross findings.

In conclusion, while systematic sampling has been the cornerstone of our autopsy procedures, our findings indicate that a more refined and targeted approach is necessary. Based on other French studies (1,3,21), it seems that few forensic departments in France have local protocols concerning systematic or targeted sampling. A multicentric study would be needed to evaluate the different practices across our territory.

A comparison with existing literature

The general usefulness of pathology has been assessed in multiple studies from the past 20 years. **Table 7** shows a comparison of some numbers from 4 other studies conducted between 2006 and 2021 (1–3,21).

Table 7. A comparison with 4 other studies

	Langlois, 2006	Lorin De La Grandmaison et al., 2010	Chatelain et al., 2012	Becas et al., 2021	Our study
No. of cases	638	428	400	64	142
Major diagnosis	28,8%	40%	21%	28%	18%
Confirmatory	36%	NC	32%	NC	34%
Non-contributory	30%	14%	26%	27%	15%
Injury characterization	NC	22%	21%	18%	20%
Manner of death left undetermined	4%	7,5%	NC	14%	33%

This comparison reveals that while the percentage of confirmatory, non-contributory and injury characterization findings is consistent, our study has a lower rate of major diagnoses and a higher percentage of undetermined manners of death after pathology analysis. This probably can be attributed to methodological differences.

As for example, for *Lorin de La Grandmaison et al*. (2010), the confirmatory group was included in the major diagnosis category, potentially inflating their percentage of major diagnoses compared to our study, which classified these groups separately. As for the higher percentage of undetermined manners of death in our study (33%), it may result from the lack of toxicology and other ancillary test results, which are often crucial in establishing a definitive cause of death. It may also stem from the initial inclusion of more cases with undetermined manner of death in our study (10% for *Lorin de La Grandmaison et al*.; 19,6% for *Becas et al*. versus 41% in our study).

Practical and ethical limitations

Histology recommendations

Clearly, routine sampling is not required in every case. The National Association of Medical Examiners (NAME) standards do outline the need to perform microscopic examination only when no gross or toxicological cause of death is present (33). Indeed, when the cause and manner of death are readily apparent, histology brings little to no additional information (1,34,35) beyond injury characterization.

As systematic sampling of macroscopically normal organs rarely contributes to forensic investigations, each sample collected during a forensic examination should be considered within a medico-legal framework. This means that every sample taken by the forensic practitioner must have a clear purpose related to the legal aspects of the case.
It is crucial for forensic doctors to develop the ability to discern which cases genuinely require histological analysis and which do not. This skill would help in optimizing resources and focusing on cases where histology can provide meaningful insights.

Forensic doctors counsel on the necessity of histology however the final decision lies with the Prosecutor's Office. This decision-making process can be influenced by various factors beyond financial strain, including the magistrate's understanding of forensic science and the tendencies of the justice system to perform histological analysis primarily when the manner of death is already known (such as homicides) (21).

In our medico-legal institute, a pathology seal is created in almost every case; however, this is not done in every forensic department. Interestingly, the absence of a systematic pathological seal in those departments doesn't seem to have effect on any court proceedings (5).

Resource allocation

Financial considerations should be mentioned as they impact the decision to order histological examinations. Since 2011, forensic departments in France receive a budget from the Ministry of Justice. However, this budget does not cover complementary analyses such as histology, which imposes an additional cost on the judicial system.

A logistical problem should also be brought forward: the increasing storage difficulties faced by some medico-legal institutes concerning non-analyzed anatomical specimens, which are sometimes retained for several years. Implementing smaller sampling schemes or limited retention policies could address this issue and also decrease the workload of forensic pathologists. This is especially relevant in our country where we currently face a shortage of such experts.

The newly established residency for forensic medicine in France does not contain any pathology training. Similarly, pathology residents don't have any training courses regarding forensic medicine. Ideally, every forensic medicine resident should complete a 6-month internship with a forensic pathologist. This would increase their competency in gross examination, improve their understanding of histological reports and enhance their ability to recommend or decline pathological examination appropriately.

Ethical aspect of whole organ retention and disposal

The practice of whole organ retention and their subsequent disposal in forensic autopsies raises significant ethical concerns. The retention of organs that hold deep symbolic and emotional significance, such as the brain and heart, is particularly sensitive. Our study showed that in 51% of cases, histological analysis was not crucial to the investigation. This high percentage raises important questions about the necessity of routine whole organ retention. Given that over half of the cases did not benefit substantially from extensive histological examination, there is a strong argument for adopting a more targeted approach to tissue sampling.

Moreover, the disposal of these organs as biological waste without consideration for cultural or religious beliefs, can be deeply troubling for families. The proposed law (30) to improve communication about human tissue retention and allow families to recover specimens for funeral arrangements is a step towards addressing these concerns.
Overall, these highlights the complex balance between the needs of the justice system, the resources available, and the respect of human dignity.

Was whole organ retention necessary in the 142 cases of our study?

Whole heart

In 13 cases, significant diagnoses were made from whole heart examination and provided the cause of death. It included 6 cases of myocarditis, 5 acute myocardial infarctions, 1 severe amyloidosis and 1 mitral valve prolapse associated with dilated cardiomyopathy in a maternal death case. Additionally, in 2 cases, whole heart was retained to further characterize injuries. In 44 cases, histology revealed a kind of cardiomyopathy which could have participated in the mechanism of death, pending toxicology and genetic results.

In acute myocarditis, the heart often appears macroscopically normal. Diagnosis is thus made by performing histology (36,37) on the left ventricular wall, the right ventricular wall and the interventricular septal wall. In the 6 cases of our study, inflammation had a diffuse pattern in the myocardium. It is likely that a diagnosis could have been reached from the histological examination of a slice of heart, as lethal cases of myocarditis are more likely to have a diffuse presentation (38). The same can be said about amyloidosis, a diffuse infiltrative disease.

Microscopic recognition of very recent myocardial infarcts (MI) can be challenging, as infarcts less than 4 hours old are usually not apparent. However, acute myocardial infarction typically results from acute thrombosis after atherosclerotic plaque disruption, which can be observed at gross examination of coronary arteries. From the 5 acute MI deaths of our series, all presented with sever coronary narrowing, meaning stenosis ranging from 70% to complete occlusion of at least one coronary artery. Sudden death is significantly associated with coronary artery narrowing when stenosis of more than 75% is present (36). Sampling of those abnormalities along with the associated myocardial territory would likely have sufficed to confirm the cause of death if needed.

Maternal deaths are quite rare in forensic practice. From the 142 cases included in our study, we identified only 2 cases (1,4%). One case was due to amniotic fluid embolism (AFE), and the other was due to cardiac changes related to pregnancy in a woman who had a prior valvular disease. In both cases, diagnoses were made through histopathology, particularly AFE which is solely a histological diagnosis (39). Recent recommendations by the Royal College of Pathologists concerning maternal deaths (40) suggest systematic heart and brain retention, as well as whole genital tract retention.

Overall, the retention of a slice of heart could probably be as productive as retaining the whole organ in most cases. However, as best practice in sudden unexpected death in less than 40 years old (41), the whole heart should continue to be retained if the cause and manner of death remain unknown after autopsy.

Whole brain

Similarly, significant diagnoses were made from fixed whole brain examinations (2 cases). One case was a known multiple sclerosis (MS) patient and the other presented cerebral hemorrhage that was missed during autopsy. Whole brain fixation also permitted to disprove 2 cases of CVA. Additionally, 14 cases of head traumas were helpful to further characterize injuries out of 20 head trauma cases included in our study. This was particularly true in criminal head trauma (8 cases).

MS is an autoimmune disease that may not present any gross abnormalities at examination of the white matter. It is therefore advised to retain the whole organ in cases of known MS to be examined by an experienced pathologist after fixation (36). The same applies to other neurological disease such as epilepsy (42).

In cases of head trauma, several specific reasons can contribute to the performance of histology: to assess diffuse axonal brain injury, to estimate wound age or to look for underlying pathology which could have caused or contributed to the head injury (19). Findings in potentially criminal cases are essential for legal assessment, and if fixation of the brain *in toto* is the optimal way to obtain reliable results (17,20), it is admitted that post-mortem CT-scan can also provide information regarding injuries (43) permitting the retention of slices of brain instead of the whole organ (44).

Relevant information can be obtained by cutting the brain fresh and retaining smaller portions, especially when no history of brain involvement exists (3,17,42). In cases of neurological medical history, brain should continue to be fixed *in toto* for both gross and microscopic examination by a pathologist.

Perspectives

Towards updated guidelines: A proposition of a standardized protocol

In terms of future forensic practices, clear sampling schemes must be developed to fit new realities without compromising the establishment of the truth. In 2006, Langlois suggested a systematic approach: "*four samples of left ventricle (each quadrant at mid-height), one of right ventricular infundibulum, one sample from each of the upper and lower lobes of both lungs, one sample from each kidney and at least one sample of brain (to include meninges) … liver (right and left lobes)*" (3). In 2012, Chatelain et al., recommended the systematic sampling of only "*brain, heart, lung, kidney and liver"* in adult cases (1).

However, as our results have shown, a more targeted sampling scheme seems to be more appropriate than a systematic approach. Furthermore, in cases where cause and manner of death are known, histological examination should no longer be performed unless to bring useful information to the investigation such as injury characterization or to answer a question about a potential prior health condition that could have contributed to the mechanism of death.

As a result, we propose this sampling protocol in cases where histology is judged to be useful by forensic practitioners:

- Heart:
    - Whole retention in cases of sudden unexpected death with no coronary disease.
    - Any other case: A transverse slice of heart to include left ventricle and right ventricle at mid-height, as shown in **Image 1** made by *Duncanson E*. (16).
- Brain:
    - Whole retention in cases of medical history of neurological disease or highly suspected neurological disorder without gross abnormalities.
    - In other cases: A slice through the cerebral hemispheres at the level of mid to posterior thalamus, incorporating the hippocampus, together with a slice of each cerebellar hemisphere and slices of the three levels of the brainstem. Additionally, in cases of head traumas, another slice passing through the basal ganglia should be taken. This is depicted in **Image 2** made by Scottish pathologists (44).
- Lungs: A sample from each lung lobe.
- Kidneys: A sample from each kidney.
- Liver: A sample from the liver.
- Additional: Any gross abnormality observed during the autopsy.

This protocol aims to balance comprehensive sampling with practical considerations, allowing for a thorough examination while addressing resource constraints.

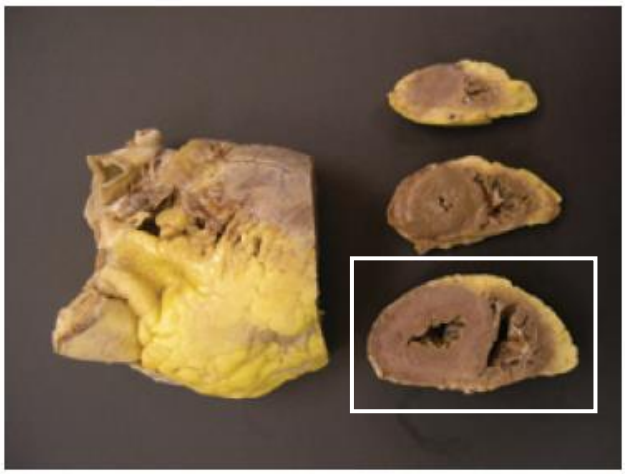

Image 1. Standard three cross-sectional of the ventricles with retention of one slice at mid-height.

Study limitations

Our study has limitations that must be acknowledged. Firstly, there may be a bias in the classification of pathological results. For example, when pathologists reported a “possible cardiomyopathy that could have contributed to the cause of death, pending toxicology results”, we classified pathology results under the "prior condition" category. This may have overestimated that particular category, but it also highlights the importance of toxicology analysis in forensic investigations. Secondly, the small number of cases where the heart and brain were sampled rather than retained whole prevented a statistical comparison to determine whether smaller samples could suffice to reveal the cause of death and conclude the investigation. Similarly, the presence of reproductive organs and the minor lesions category provided an aberrant statistical number, probably due to the small number of cases concerned. A future multicentric study is needed to evaluate this issue properly.

Our study also highlighted communication issues between forensic practitioners and pathologists. Pathologists often lacked crucial information about the case, including the circumstances of death, autopsy findings, and/or the reasons for recommending pathology. Improving communication would enhance the relevance and utility of pathological examinations.

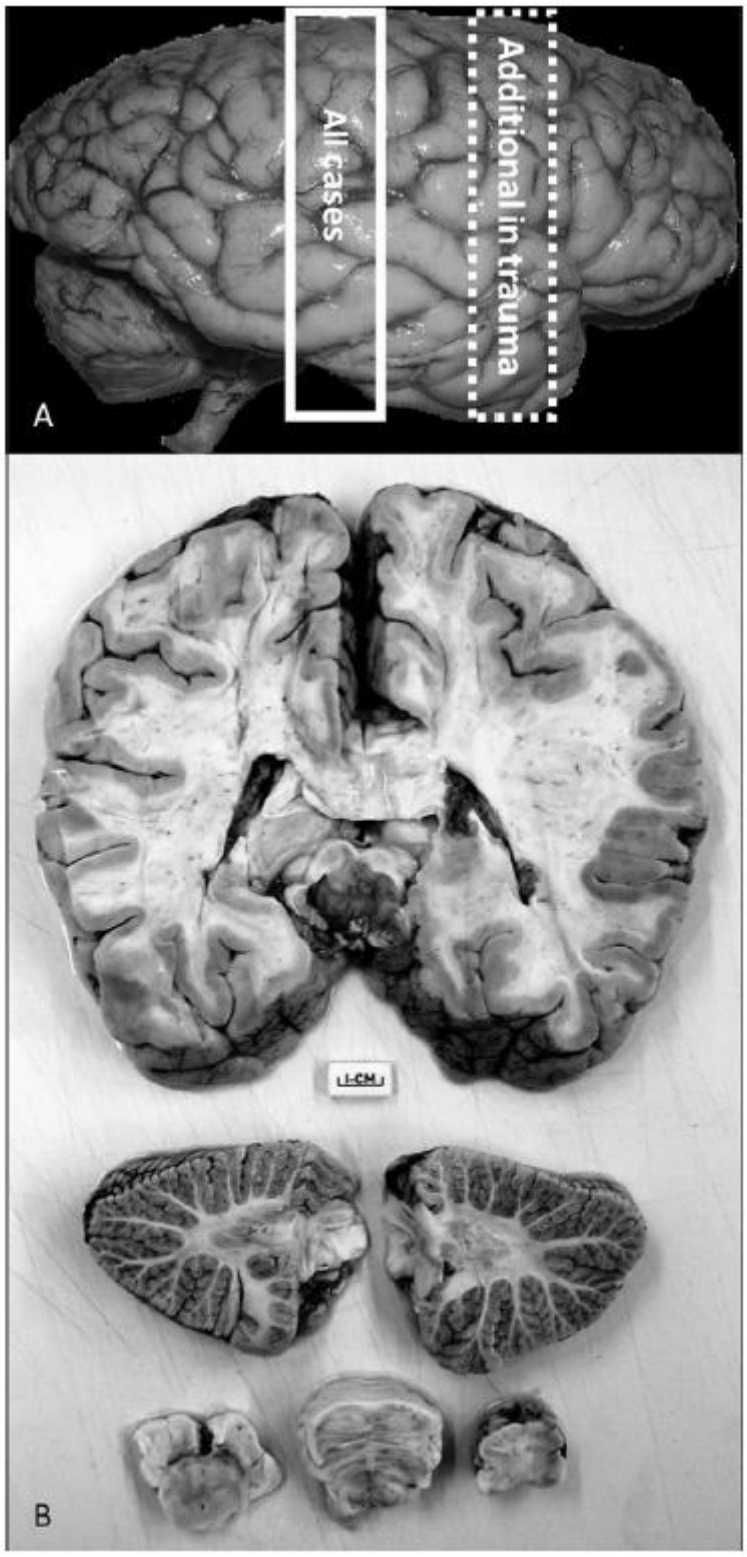

Image 2. Neuropathology sampling protocol by *McEwan, 2011*

Conclusion

In our forensic department, brain and heart are mistakenly retained whole in a majority of cases. This practice has significant consequences, including potential emotional distress for families, ethical concerns and increased workload for pathologists. Even more so because histology proves useful in only about half of the time. Regarding histology of the heart, it provided important additional information in 44% of cases and for the brain, in only 14% of cases. Based on literature and recommendations from scientific societies, we have proposed a targeted sampling procedure to reduce whole organ retention without compromising the quality of forensic investigations. This protocol should be sufficient, provided that a thorough gross examination is performed, and that forensic doctors rely more confidently on their clinical judgment. Further studies are needed to assess the non-inferiority of this approach, and if it meets forensic standards.

Disclosure

The author does not report any conflicts of interest.

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Annex

Recommendation No. R (99) 3 – B. Brinkmann. Harmonisation of Medico-legal autopsy rules. Int J Legal Med 1999; 113:1-14.

RECOMMENDATION No. R (99) 3 OF THE COMMITTEE OF MINISTERS TO MEMBER STATES ON THE HARMONISATION OF MEDICO-LEGAL AUTOPSY RULES

(Adopted by the Committee of Ministers on 2 February 1999 at the 658th meeting of the Ministers' Deputies)

The Committee of Ministers, under the terms of Article 15.b of the Statute of the Council of Europe,

Considering that the aim of the Council of Europe is to achieve a greater unity between its members;

Having regard to the principles laid down in the Convention for the Protection of Human Rights and Fundamental Freedoms and, in particular, the prohibition of torture or inhuman or degrading treatment or punishment, and the right to life;

Conscious that it is normal practice for autopsies to be carried out in all Council of Europe member States to establish the cause and manner of death for medico-legal or other reasons or to establish the identity of the deceased;

Considering the importance of compensation for victims and families in criminal and civil proceedings;

Underlining the need for investigation, description, photographic documentation and sampling during medico-legal autopsy to follow primarily medical and scientific principles and simultaneously consider legal requirements and procedures;

Conscious that the increasing mobility of the population throughout Europe and the world, as well as the increasing internationalisation of judicial proceedings, require the adoption of uniform guidelines on the way autopsies are to be carried out and on the way autopsy reports are to be established;

Considering the Council of Europe Agreement on the Transfer of Corpses (European Treaty Series No. 80) and having regard to the difficulties often experienced by the receiving country when a dead body is repatriated from one member state to another;

Aware of the importance of proper autopsy procedures, in particular with a view to bringing to light illegal executions, and murders perpetrated by authoritarian regimes;

Underlining the need to protect the independence and impartiality of medico-legal experts, as well as to make available the necessary legal and technical facilities for them to carry out their duties in an appropriate way and to promote their training;

Considering the importance of national quality control systems to ensure the proper performance of medico-legal autopsies;

Underlining the need to strengthen international co-operation with a view to the progressive harmonisation of medico-legal autopsy procedures at a European level;

Having regard to Recommendation 1159 (1991) on the harmonisation of autopsy rules adopted, at its 43rd Ordinary Session, by the Parliamentary Assembly of the Council of Europe;

Having regard to the Model Autopsy Protocol of the United Nations, endorsed by the General Assembly of the United Nations in 1991;

Taking into account the "guide on disaster victim identification" adopted by the International Criminal Police Organisation (Interpol) General Assembly in 1997,

1. Recommends the governments of member states:

i. to adopt as their internal standards the principles and rules contained in this recommendation;
ii. to take or reinforce, as the case may be, all appropriate measures with a view to the progressive implementation of the principles and rules contained in this recommendation;
iii. to set up a quality assurance programme to ensure the proper implementation of the principles and rules contained in this recommendation.

2. Invites the governments of member states to inform the Secretary General of the Council of Europe upon his or her request of the measures taken to follow up the principles and rules contained in this recommendation.

Principles and rules relating to medico-legal autopsy procedures

Scope of the recommendation

1. In cases where death may be due to unnatural causes, the competent authority, accompanied by one or more medico-legal experts, should where appropriate investigate the scene, examine the body and decide whether an autopsy should be carried out.

2. Autopsies should be carried out in all obvious or suspected unnatural death, even where there is a delay between causative events and death, in particular:

a. homicide or suspected homicide;
b. sudden, unexpected death, including sudden infant death;
c. violation of human rights such as suspicion of torture or any other form of ill treatment;
d. suicide or suspected suicide;
e. suspected medical malpractice;
f. accidents, whether transportational, occupational or domestic;
g. occupational disease and hazards;
h. technological or environmental disasters;
i. death in custody or death associated with police or military activities;
j. unidentified or skeletalised bodies.

3. Medico-legal experts must exercise their functions with total independence and impartiality. They should not be subject to any form of pressure and they should be objective in the exercise of their functions, in particular in the presentation of their results and conclusions.

Principle I – Scene investigation

a. General principles

1. In case of obvious or suspected unnatural death, the physician who first attended the dead body should report to the competent authorities, the latter deciding whether an examination should be carried out by a qualified medico-legal expert or by a physician familiar with medico-legal examination.

2. Particularly in cases of homicide or suspicious death, medico-legal experts should be informed without delay and, where appropriate, go immediately to the place where the body is found and have immediate access there. In this respect, there should be an adequate structure of co-ordination among all persons involved and, in particular, among judicial bodies, medico-legal experts and police.

b. Examination of the body

1. Role of the police

The following tasks, among others, should be carried out by police officers:

a. record the identities of all persons at the scene;
b. photograph the body as it is found;
c. make sure that all relevant artifacts are noted, and that all exhibits, such as weapons and projectiles, are seized for further examination;
d. in agreement with the medico-legal expert, obtain identification of the body and other pertinent information from scene witnesses, including those who last saw the decedent alive, where available;
e. protect the deceased's hands and head with paper bags, under the control of the medico-legal expert;
f. preserve the integrity of the scene and surroundings;

2. Role of the medico-legal expert

The medico-legal expert should without delay:

a. be informed of all relevant circumstances relating to the death;
b. ensure that photographs of the body are properly taken;
c. record the body position and its relation to the state of the clothing and to the distribution pattern of rigor mortis and hypostasis, as well as the state of post-mortem decomposition;
d. examine and record the distribution and pattern of any blood stains on the body and at the scene, as well as other biological evidence;
e. proceed to a preliminary examination of the body;
f. except where the body is decomposed or skeletal, note the ambient temperature and deep-rectal temperature of the body, and estimate the time of death by recording the degree, location and fixation of rigor mortis and hypostasis, as well as other findings;
g. make sure that the body is transported and stored in a secure and refrigerated location in an undisturbed state.

Principle II – Autopsy physicians

Medico-legal autopsies should be performed, whenever possible, by two physicians, of whom at least one should be qualified in forensic pathology.

Principle III – Identification

In order to ensure that proper identification of the body is carried out in accordance with the disaster victim identification guide adopted by the General Assembly of Interpol in 1997, the following criteria should be considered: visual recognition, personal effects, physical characteristics, dental examination, anthropological identification, finger prints and genetic identification.

1. Visual identification

Visual identification of a body should be carried out by relatives or persons who knew and have recently seen the decedent.

2. Personal effects

A description of clothing, jewellery and pocket contents should be recorded. These may assist correct identification.

3. Physical characteristics

Physical characteristic should be recorded through an external and an internal examination.

4. Dental examination

Where appropriate, the examination of teeth and jaws should be carried out by a dentist with medico-legal experience.

5. Anthropological identification

Whenever human material is skeletised or in an advanced stage of decomposition, an anthropological identification should be carried out, if necessary.

6. Fingerprints

Where appropriate, fingerprints should be taken by police officers. A close collaboration should exist between all experts involved.

7. Genetic identification

Where appropriate, genetic identification should be carried out by an expert in forensic genetics.

It is appropriate to take biological samples from the deceased in order to assist genetic identification. Measures should be taken in order to avoid contamination and guarantee appropriate storage of biological samples.

Principle IV – General considerations

1. Medico-legal autopsies and all related measures must be carried out in a manner consistent with medical ethics and respecting the dignity of the deceased.

2. Where appropriate, the closest relatives should be given an opportunity to see the corpse.

3. Before beginning the autopsy, the following minimum rules should be applied:

a. record the date, time and place of autopsy;
b. record the name(s) of the medico-legal expert(s), assistant(s) and all other persons present at the autopsy with indication as to the position and role of each one in the autopsy;
c. take colour photographs or video, where appropriate, of all relevant findings and of the dressed and undressed body;
d. undress the body, examine and record clothing and jewellery, verify the correspondence between injuries on the body and clothing;
e. where appropriate, take X-rays, particularly in cases of suspected child abuse, and for identification and location of foreign objects.

4. Where appropriate, before beginning the autopsy, body orifices should be appropriately swabbed for the recovery and identification of biological trace evidence.

5. If the decedent was hospitalised prior to death, admission blood specimens and any X-rays should be obtained as well as hospital records.

Principle V – Autopsy procedures

I. External examination

1. The examination of the clothing is an essential part of the external examination and all findings therein are to be clearly described. This is especially important in those cases where the clothing has been damaged or soiled: each area of recent damage must be described fully and relevant findings are to be related to the site of injuries on the corpse. Discrepancies in such findings are also to be described.

2. The description of the body following an external examination must include:

a. age, sex, build, height, ethnic group and weight, nutritional state, skin colour and special characteristics (such as scars, tattoos or amputations);
b. post-mortem changes, including details relating to rigor and post mortem hypostasis – distribution, intensity, colour and reversibility – and putrefaction and environmentally induced changes;
c. findings on a primary external inspection and description which, if required, include sampling of stains and other trace evidence on the body surface and a reinspection after removal and cleaning of the body;
d. inspection of the skin of the posterior surfaces of the corpse;
e. description and careful investigation of the head and the facial orifices includes: colour, length, density and distribution of hair (and beard); nasal skeleton; oral mucosa, dentition and tongue; ears, retro-auricular areas and external meati; eyes: colour of irises and sclerae, regularity and appearance of pupils, sclerae, conjunctivae; skin (presence and absence of petechiae to be described); if fluids have been evacuated from facial orifices, their colour and odour;
f. neck: checking for excessive mobility, presence and absence of abrasions, other marks and bruising (including petechiae) over the entire circumference of the neck;
g. thorax: shape and stability; breasts; aspect, nipples and pigmentation;
h. abdomen: external bulging, pigmentation, scars, abnormalities and bruising;
i. anus and genitals;
j. extremities: shape and abnormal mobility, abnormalities; injection marks and scars; palmar surfaces, finger and toe nails;
k. material findings under fingernails.

3. All injuries, including abrasions, bruises, lacerations and other marks have to be described by shape, exact measurement, direction, edges, angles and location relative to anatomical landmarks. Photographs should be taken. Bite marks shall be swabbed, and casts made where necessary.

4. Signs of vital reaction around wounds, foreign particles inside wounds and in their surroundings and secondary reactions, such as discolouration, healing and infections must also be described.

5. The investigation of cutaneous and sub-cutaneous bruising may require local skin incision.

6. Where appropriate, specimens from wounds must be removed for further investigations, such as histology and histochemistry.

7. All signs of recent or old medical and surgical intervention and resuscitation must be described. Medical devices must not be removed from the body before the intervention of the medico-legal expert.

8. A decision has to be taken at this stage as to the strategies of investigation and the necessity of documentation by X-rays and other imaging procedures.

II. Internal examination

A. General

1. All relevant artifacts produced by the dissection and from sampling procedures, must be documented.

2. All three body cavities head, thorax and abdomen must be opened layer by layer. Where appropriate, the vertebral canal and joint cavities should be examined.

3. Examination and description of body cavities include: an examination for the presence of gas (pneumothorax), measurement of volume of fluids and blood, appearance of internal surfaces, intactness of anatomical boundaries,

external appearance of organs and their location; adhesion and cavity obliterations, injuries and haemorrhage.

4. The demonstration and dissection of the soft tissues and musculature of the neck have to be components of all medico-legal autopsies (see the paragraph concerning special procedures).

5. All organs must be examined and sliced following established guidelines of pathological anatomy. This includes opening of all relevant vessels, for example, intracranial arteries, sinuses, carotid arteries, coronary arteries, pulmonary arteries and veins, aorta and vessels of the abdominal organs, femoral arteries and lower limb veins. Relevant ducts have to be dissected, for example, central and peripheral airways, biliary ducts and ureters. All hollow organs have to be opened and their content described by colour, viscosity, volume (samples should be retained, where appropriate). All organs have to be sliced and the appearance of the cut surface described. If injuries are present, the dissection procedure may have to vary from the normal one: this should be appropriately described and documented.

6. All internal lesions and injuries must be precisely described by size and location. Injury tracks must be described in order to include their direction as regards the organ anatomy.

7. The weight of all major organs must be recorded.

B. Detailed

1. Head

a. Before opening the skull, the periosteum must be scraped off in order to display or exclude any fractures.
b. The head examination procedure must allow the inspection and description of the scalp, external and internal surfaces of the skull and of the temporal muscles.
c. The thickness and appearances of the skull and sutures, the appearances of the meninges, the cerebrospinal fluid (CSF), the wall structure and contents of cerebral arteries and sinuses must be described. The description of the bones must also include an examination of their intactness, including the connection between the skull and the first two vertebrae.
d. In obvious or suspected head injury (for example, if a detailed examination is required or if autolysis or putrefaction is present) fixation of the whole brain is recommended before its dissection.
e. Middle ears must be always opened and nasal sinuses where indicated.
f. The soft tissue and skeleton of the face is dissected only in relevant cases, using a cosmetically acceptable technique.

2. Thorax and neck

The opening of the thorax must be performed using a technique which allows the demonstration of the presence of pneumothorax and the inspection of the thorax walls, including the postero-lateral regions. In situ dissection of the neck must display the details of its anatomy.

3. Abdomen

The opening procedure of the abdomen must allow an accurate examination of all layers of the walls, including the postero-lateral regions. In situ dissection is necessary in certain cases, particularly for the demonstration of injury tracks and evacuation of fluids. Dissection of organs should observe anatomical continuity of systems, where possible. The whole intestine must be dissected and its contents described.

4. Skeleton

a. The examination of the thoracic cage, the spine and the pelvis must be part of the autopsy procedure.
b. Where appropriate traumatic deaths need a precise dissection of the extremities, possibly complemented by X-ray examination.

5. Special procedures

a. If there is any suspicion of neck trauma, the brain and thoracic organs are to be removed prior to the dissection of the neck, to enable detailed dissection to take place in a bloodless field.
b. If there is a suspicion of air embolism, pre-autopsy radiology of the thorax must be performed. The first stage of the autopsy in such a case must be a careful partial opening of the thorax and dislocation of the lower three-quarters of the sternum with the subsequent opening of the heart under water, allowing the measurement and sampling of escaping air or gas.
c. For the demonstration of particular injury patterns, deviation from the normal procedure of dissection has to be accepted, provided that such procedures are specifically described in the autopsy report.
d. The dissection in traumatic deaths must include a full exposure of the soft tissues and musculature on the back of the body. The same procedure must be applied to the extremities (so called "peel-off" procedure).
e. In suspected or overt sexual assaults, the sexual organs are to be removed "en bloc" together with the external genitalia, rectum and anus, before they are dissected. Relevant swabs of orifices and cavities must be taken prior to this procedure.

6. Sampling

The scope of the sampling procedure is to be case-dependent. However, the following minimum rules should be applied:

a. in all autopsies, the basic sampling scheme includes specimens from the main organs for histology and peripheral blood sampling (such as for alcohol and drug analyses and genetic identification), urine and gastric contents. All blood samples must be peripheral blood and not heart or thoracic;
b. if the cause of death cannot be established with the necessary degree of certainty, sampling includes addi-

tional specimens and fluids for metabolic studies and thorough toxicology. This includes blood, vitreous humour, CSF, bile, hair samples and further relevant tissues;
c. if death is related to physical violence, sampling includes the injuries, for example to determine wound age and any foreign materials in the wounds;
d. if reconstructions are desirable, the removal of bones and osseous compartments may become necessary;
e. if identification is the predominant aim, the removal of jaws and other bones may be necessary;
f. if strangulation or the application of physical force to the neck is suspected or diagnosed, the entire neck structures, musculature and neurovascular bundles must be preserved for histology. The hyoid bone and the laryngeal cartilages must be dissected very carefully;
g. biological samples must be collected in tightly closed jars, properly preserved and placed under seal and transported to the laboratory in perfect safety;
h. certain specimens and fluids need to be sampled in a special way and analysed without delay.

7. Release of the body

After a medico-legal autopsy has been carried out, medico-legal experts should ensure that the body is returned in a dignified condition.

Principle VI – Autopsy report

1. The autopsy report is as important as the autopsy itself, as the latter is of little value if the findings and opinions of the medico-legal expert are not communicated in a clear, accurate and permanent document. The autopsy report should be an integral part of the autopsy procedure and be drafted carefully.

2. The report should therefore be:

a. full, detailed, comprehensive and objective;
b. clear and comprehensible not only to other doctors, but also to non-medical readers;
c. written in a logical sequence, well-structured and easy to refer to in various sections of the report;
d. be in a legible and permanent form, with hard paper copy even if it is retained in electronic storage;
e. be written in a discursive "essay" style;

3. When drafting an autopsy report, the following minimum content should be included:

a. legal preface to fulfil statutory requirements, if needed;
b. serial number, computer retrieval coding and International Classification of Disease Code (ICD) code;
c. full personal details of deceased (including name, age, sex, address and occupation) unless unidentified;
d. date, place and time of death, where known;
e. date, place and time of autopsy;
f. name, qualifications and status of medico-legal expert(s);
g. persons present at the autopsy and their function;
h. name of the authority commissioning the autopsy;
i. person(s) identifying the body to the medico-legal expert;
j. name and address of the medical attendant of the deceased;
k. a synopsis of the history and circumstances of the death, as given to the medico-legal expert by the police, judges, relatives or other persons, as well as information contained in the file, where available;
l. description of the scene of death, if attended by the medico-legal expert; reference should be made to the provisions contained in Principle I above;
m. external examination; reference should be made to the provisions of Principle V above;
n. internal examination by anatomic systems, together with a comment on every organ. Reference should be made to the provisions of Principle V above;
o. a list of all samples retained for toxicology, genetic identification, histology, microbiology and other investigations should be included; all such specimens should be identified and attested by the medico-legal expert according to the legal system of the state concerned, for continuity of evidence;
p. results of ancillary investigations, such as radiology, odontology, entomology and anthropology should be included, when such results are available;
q. one of the most important parts of the autopsy report is the evaluation of the significance of the accumulated results by the medico-legal expert. After termination of the autopsy, evaluation is usually provisional because later findings and later knowledge of other circumstantial facts can necessitate alteration and modification. Medico-legal experts must interpret the overall findings so that the maximum information and opinion can be offered. Also questions that have not been raised by the competent authority must be addressed if they could be of significance;
r. based on the final interpretation, the cause of death (in the International Classification of Disease should be given. Where several alternatives for the cause of death exist and the facts do not allow a differentiation between them, the medico-legal expert should describe the alternatives and, if possible, rank them in order of probability. If this is not possible, then the cause of death should be certified as "Unascertained";
s. the report should be finally checked, dated and signed by the medico-legal expert(s).

4. The date of the autopsy and the date of the provisional report should never be more than a day or two apart. The date of the autopsy and the date of the final report should be as close together as possible.

Appendix to Recommendation No. R (99) 3

Specific procedures (selected examples)

1. Constriction of neck (hanging, manual and ligature strangulation)

The examination of the scene where the body was found is extremely important: for example the presence of a chair or similar platform; fastening of the strangulation device; technique of tying of the knot; adhesive taping of hands and objects for trace evidence:

- Strangulation marks: depth, width, intermediate rings, direction, suspension point, raised ridges of skin, zones of hyperaemia, presence of duplicate strangulation marks; further specific neck injuries: dried excoriations due to slippage of the implement, marks due to textile weave pattern and structure, distribution of petechiae in the skin, bruising, scratch marks, blisters in the strangulation mark.
- Bleeding from facial orifices. Differences in widths of the pupils, localization of hypostasis, presence and distribution of congestion.
- Injuries due to convulsions, defensive injuries, injuries due to being held forcibly. Dissection of the soft tissues, of the musculature and of the organs of the neck in a bloodless field is essential.

2. Drowning / Immersion

Note carefully the following findings: foam at the mouth, cutis anserina, maceration, mud and algae, lesions due to water animals, injuries due to surroundings (for example rocks and ships), loss of nails, skin, localization of livor mortis.

Technique: sampling of gastric contents, precise description of the lungs (weight, measurement, extent of emphysema), sampling, lung fluid, liver and other tissues, for the possible demonstration of diatoms and other contaminants.

If required, sampling of drowning medium (for example river, bath water) should be carried out.

3. Sexually motivated murder

The inspection and documentation of the scene of crime, e.g. relative to the injury pattern, is especially important. All injuries must be photographed together with a scale. If required, the body surfaces must be investigated under UV light and taped. Search for and sampling of foreign biological material must include pubic hairs and secretions on the body surface as for instance originating from bites. Such material must be preserved carefully for DNA investigation and protected against contamination. "En bloc" dissection of the genital organs is strongly recommended. It is also necessary to proceed to the careful removal and sampling of material under the fingernails and control hairs.

4. Death from child abuse and neglect

State of nutrition and general care, thorough description and documentation of external injuries and scars, thorough examination for bone fractures (X-ray), must be evaluated.

Consider the removal of a variety of tissues: for example all injuries, regional lymph nodes in malnutrition, endocrine organs, immuno-competent tissues, specimens from different parts of the intestine.

5. Infanticide / still-birth

Special techniques of dissection are necessary to expose the falx cerebri and the tentorium cerebelli; describe the site of caput succedaneum; remove all fractures "en bloc"; investigate all bone centres of ossification (size and presence). Special care is to be applied to the thoracic organs: degree of inflation of the lungs, flotation test "en bloc" and "en detail". However, the limitations of the flotation test must be appreciated. All malformations must be described. As regards abdominal organs, gas content of the intestine must be investigated. The umbilical cord and the placenta must be subject to morphological and histological examination.

6. Sudden death

A subdivision into three main categories relative to the further strategy after gross examination is useful:

a. findings that obviously explain the sudden occurrence of death (for example haemopericardium, aortic rupture). Cases belonging to this category can usually be regarded as sufficiently solved;
b. findings that could explain the death but allow other explanations. Cases belonging to this category necessitate the exclusion of, for example,. poisoning and possibly histological proof of recent or chronic alterations relative to the cause of death;
c. findings are either nil/minimal or do not explain the occurrence of death. Cases belonging to this category will usually require extensive further investigations. This is especially so with sudden infant death cases. In such cases a more comprehensive investigative scheme is essential.

7. Shooting fatalities

The following should be carried out:

- extensive account on the scene of the incident, of weapons involved, of types of bullets, of sites of "environmental" damage, of cartridge cases and of relative positions of persons involved;
- thorough examination of the clothing and description of relevant damage and careful sampling;
- thorough investigation and documentation of any blood (splashes) on the body surfaces (including clothing and hands);
- precise description of bullet entry and exit wounds relative to anatomical landmarks and distances from the soles of the feet and bullet tracks within the body;
- description of any impression marks of the muzzle;
- excision of uncleaned skin specimens surrounding entry and exit wounds;
- X-ray before and/or during autopsy (where necessary);
- determination of bullet tracks and their direction(s);
- final determination of direction(s) of fire, of the succession of shots, of intra-vital occurrence, of the victim's position (s).

8. Death caused by explosive devices

a. As well as evaluating the cause of death, autopsy is essential to assist in reconstructing the nature of the explosion and identifying the type and maker of the explosive device, especially in aircraft sabotage or other terrorist actions.
b. Full X-ray of the body must be made to detect and localise any metallic objects, such as detonator components, which may lead to the identification of the explosive device.
c. The pattern of injury may indicate that the dead person was a perpetrator of the explosion, for example maximum injury in the lower abdominal region suggests that he or she carried the device on his or her lap during a premature explosion.
d. At autopsy, all foreign objects in the tissues, identified on X-rays, must be carefully preserved for forensic examination.
e. Samples of tissues, clothing, etc., must be retained for chemical analysis to identify the type of explosive.

9. Blunt and/or sharp force injuries

The following should be carried out:

- examination of the weapons or objects that are possibly involved (especially their dimensions);
- extensive examination and inspection of clothing (including damage, stains);
- careful dissection and description of all tracks (layer by layer) including their dimensions and weapon-related traces, signs of vitality.

10. Fire Deaths

The following should be carried out:

- examination of remains of clothing, – specific types and shapes of skin combustions;
- search for heat-related alterations and peculiarities;
- demonstration/exclusion of fire accelerants.;
- search for signs of vitality: carbon monoxide, HCN, soot inhalation, skin lesions.

11. Suspicion of intoxication (General Outlines)

11.1 Where anatomical findings do not reveal a cause of death and/or there is vague suspicion of poisoning, basic sampling should include peripheral blood, urine, stomach contents, bile, liver and kidney.

11.2 If specific suspicion arises, sampling should be group-related as follows:

- hypnotics, sedatives, psycho-active drugs, cardiac drugs and analgesics, pesticides: as aforementioned under (11.1);
- drugs of abuse: as aforementioned under (11.1) and additionally cerebrospinal fluid, brain tissue, injection marks, hairs;
- volatile fat-soluble substances such as fire accelerant and solvents: as aforementioned under (11.1) and in addition: blood from left ventricle, brain tissue, subcutaneous fat tissue, lung tissue, clothing;
- nutritional intoxication: as aforementioned under (11.1) and in addition: intestinal contents, if possible taken from 3 different sites;
- suspicion of chronic intoxication (heavy metals, drugs, pesticides etc.) as aforementioned under (11.1) and in addition: hairs (tufts), bones, fat tissue, intestinal contents.

12. Decomposed bodies

The presence of decomposition does not remove the need for a full autopsy.

Radiological examination will exclude bony injury, the presence of foreign bodies, for example bullets. Toxicological studies (particularly estimation of alcohol concentrations) should be carried out but interpreted with great caution.

Vu, le Directeur de Thèse

Vu, le Doyen

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51 pages – 7 tableaux – 7 figures – 2 images

Résumé :

Introduction : L'analyse histologique après une autopsie médico-légale n'est pas systématique en France. Le médecin légiste prélève les organes (en entier ou des fragments) qui lui paraissent pertinents mais la décision de l'analyse revient au magistrat responsable de l'enquête. Il n'existe pas de recommandations validées concernant l'échantillonnage d'organes en anatomopathologie. Toutefois, ces organes n'étant pas restitués aux défunts, nous nous sommes confrontés récemment aux plaintes de familles trouvant des prélèvements systématiques injustifiés. Dans ce contexte, nous avons mené une étude dont l'objectif était de déterminer quels organes prélevés pour analyses anatomopathologiques avaient un impact sur la conclusion médico-légale, et plus particulièrement s'il y avait un intérêt à prélever le cœur et le cerveau en entier.

Matériel et méthodes : Nous avons mené une étude sur les comptes rendus d'autopsie et d'analyse anatomopathologique des corps autopsiés à l'Institut Médico-Légal de Tours entre 2020 et 2022. L'utilité des prélèvements systématiques d'organes lors d'autopsies médico-légales a été évaluée, en classant les conclusions médico-légales en 7 catégories : 4 dites « utiles » (diagnostic, discordante, caractéristique lésionnelle, état antérieur) et 3 « inutiles » (confirme, non contributif, lésions mineures).

Résultats : Sur 142 dossiers analysés, le cœur a été prélevé en entier dans 94 % des cas et le cerveau en entier dans 87% des cas. L'analyse anatomopathologique de ces organes a permis la catégorisation des conclusions médico-légales dans une des catégories dites « utiles » dans 44 % des cas pour le cœur et 14 % des cas pour le cerveau. Par ailleurs, la réalisation de l'examen histopathologique s'est avérée utile dans 49 % des cas, peu importe les organes prélevés, fournissant des informations diagnostiques cruciales dans 18 % des cas, caractérisant des lésions dans 20 % des cas, et révélant des conditions médicales préexistantes ayant pu participer au décès dans 10 % des cas.

Discussion : Parmi les éléments d'intérêt médico-légaux apportés par le prélèvement du cœur et le cerveau, il est probable que dans la majorité des cas, un examen macroscopique de qualité et un échantillonnage ciblé auraient mené à la même conclusion. De plus, dans 51 % des cas, l'expertise anatomopathologique n'a pas apporté d'éléments supplémentaires aux données macroscopiques, questionnant l'utilité des prélèvements systématiques. Ainsi, nous proposons un protocole d'échantillonnage standardisé visant à équilibrer la qualité des investigations médico-légales avec les contraintes pratiques actuelles.

Mots clés : Médecine légale – Autopsie médico-légale – Anatomopathologie médico-légale – Prélèvements d'organes – Pratiques autopsiques – Enquête décès

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