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Minireview

Cardiac dissection techniques for pathoanatomical research on myocardial hypertrophy and anatomical teaching

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ABSTRACT

Background: Various cardiac dissection techniques are used in basic pathoanatomical research on cardiovascular diseases and anatomical teaching. In contrast, diagnostic routine techniques in pathology and legal medicine have subject-specific recommendations. However, these recommendations do not outline specific techniques for the determination of heart weight and myocardial hypertrophy. Thus, the present manuscript outlines cardiac dissection techniques that may be employed in pathoanatomic and autopsy-based research and anatomical teaching.
Methods: A narrative literature review and discussion of established cardiac dissection techniques for diagnostic routine (Short-Axis and Inflow-Outflow methods), anatomical teaching (combined Window and Base-of-Heart methods) and pathoanatomic research on myocardial hypertrophy (Fulton and Chamber Partition techniques).
Results: Cardiac dissection techniques such as the Fulton method allow an in-depth assessment of ventricular hypertrophy by capturing the weight of specific parts of the heart. Such techniques, which are outside current recommendations for diagnostic routine, are desirable for research purposes. The examples in this review show how different dissection techniques visualize different cardiac structures for anatomical teaching.
Conclusion: Various cardiac dissection techniques enable the in-depth assessment of myocardial hypertrophy and heart weight. For anatomical teaching, the simultaneous display of several dissection techniques improves visualization of cardiac structures and supports a better understanding of the topographic cardiac anatomy. In pathoanatomical research on cardiovascular diseases, certain dissection techniques beyond those employed in diagnostic routine improve the evaluation of myocardial hypertrophy and heart weight.

1. Introduction

International recommendations (Stone et al., 2012), guidelines (Basso et al., 2017), and standard textbooks (Maleszewski et al., 2023) suggest techniques for human heart dissection. International recommendations and guidelines focus on the diagnostic routine both in pathology and legal medicine (Basso et al., 2017; Stone et al., 2012). In contrast, standard textbooks tend to outline a greater diversity of cardiac dissection techniques, while still focusing on the case work routine (Maleszewski et al., 2023). However, the guidelines, textbooks, and recommendations agree that the so-called Short-Axis method (Fig. 1)—performing laminating cross-sections followed by opening the basal cardiac remains in the direction of the blood flow—is particularly important for diagnostic routine (Basso et al., 2017; Maleszewski et al., 2023; Stone et al., 2012). Because of its decades-long use for diagnostic purposes, the Inflow-Outflow method (Fig. 2) where all cardiac chambers are opened in the order of the blood flow—is also considered acceptable for use in diagnostic routine (Maleszewski et al., 2023). The aforementioned recommendations ensure reproducible and reliable diagnoses (Basso et al., 2017; Stone et al., 2012), whereas particular demands in the routine of anatomists are not taken into account.

From an anatomical perspective, cardiac dissection is of particular interest in the context of anatomical teaching and basic pathoanatomical research. The complex and functional cardiac anatomy (Mori et al.,

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2019) needs to be visualized and assessed alongside its high variability [e.g., spectrum of coronary variations (Vilallonga, 2003)]. Thus, anatomists, who are not bound to the needs of a standardized diagnostic routine, might apply a broader spectrum of cardiac dissection techniques following the specific needs in teaching and research. With the understanding of cardiovascular anatomy considered as the “dawn of cardiovascular pathology” (Zampieri et al., 2016),[1] dissection techniques beyond the diagnostic routine are of interest to all medical disciplines involved in the diagnosis of cardiovascular pathologies including clinical subjects such as radiology (Mori et al., 2019), surgery (Anderson, 2000), and pediatrics (Anderson and Shirali, 2009; Jacobs et al., 2007). For example, specialized dissection techniques have been developed to correlate the cardiac structure with electrocardiographic findings (Lev and McMillan, 1959) or to reflect clinical advances in tomographic imaging techniques (Edwards, 1984; Nazarian et al., 1987). Even today, new dissection techniques that incorporate developments such as post-mortem imaging (e.g., computed tomography) continue to be developed (Yamasaki et al., 2024).[2] Given this interdisciplinary and translational context, the present minireview describes the topographic anatomy of the heart following according to international *clinical* guidelines and recommendations [(Lang et al., 2006; Mitchell et al., 2019), Fig. 3].

The cardiac anatomy is of particular interest in the context of hypertrophic cardiomyopathy (HCM)[3] (Federspiel et al., 2024b, 2024a), the most frequent genetic cardiac disorder (Ommen et al., 2024). It is associated with sudden cardiac death (SCD)[4] (Ommen et al., 2024) and is considered a global burden (Maron et al., 2018). In the context of HCM

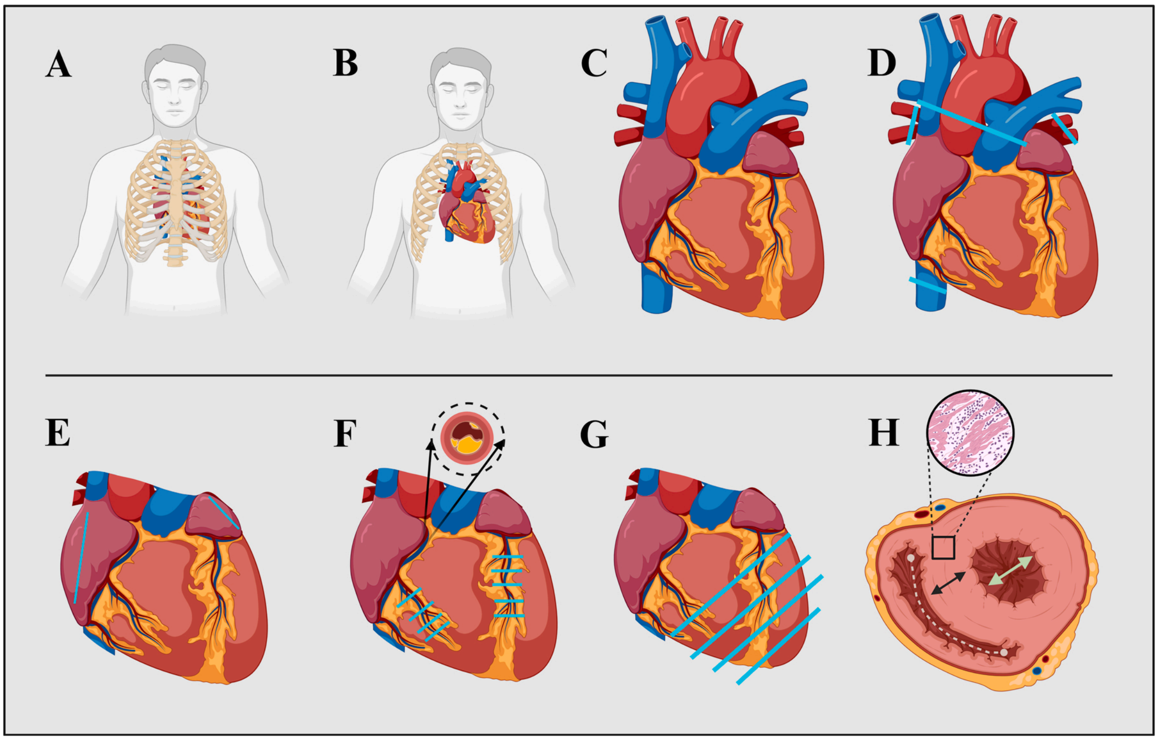

Fig. 1. Scheme Short-Axis method, (A–D) show the removal of the heart from the thorax, the prerequisite for all cardiac dissection techniques discussed in the present minireview. (E–H) show the different steps of the Short-Axis method. (A) Exposure of the anterior aspects of the sternum and the rib cage. (B) Removal of the anterior aspects of the sternum and the medial parts of the ribs to open the thorax and expose the mediastinum. Opening of the pericardium to (C) expose the heart and the large vessels. (D) Transecting the large vessels in order to harvest the heart from the thorax. Cleaning of the heart. Trimming the large vessels and inspecting the semilunar valves. (E) Posterosuperior opening of the atria. Cleaning and inspection of the atria and atrioventricular valves. (F) Applying laminating perpendicular cuts through the coronaries to produce approximately 0.5-cm-thick cross sections. Inspection of the coronaries. (G) Performing laminating cross sections through the ventricular myocardium (approximately 1 cm thickness) starting at the apex and stopping basal to the atrioventricular valves. Longitudinal opening of the basal remainders of the heart, analogous to the Inflow-Outflow method (see Fig. 2). Inspection of the basal parts of the heart. (H) Detailed examination of the cross sections, noting the size of the left ventricular cavity, the shape of the right ventricle, and wall thicknesses of the interventricular septum, right ventricle, and left ventricle. Standardized sampling for subsequent histological analyses. [Created in BioRender; agreement number: MD28EA7WHJ; figures in (Basso et al., 2017) served as paragon.].

[1] This quote from Zampieri et al. is underpinned by the achievements of cardiac experts such as Maude Abbott (Fraser, 2006; Wright et al., 2017), Robert H. Anderson (Sternick and Sánchez-Quintana, 2021), Gaetano Thiene (Frescura and Thiene, 2014), and Christina Basso (Basso et al., 2019, 2015), which have driven clinical and pathological advances for decades.

[2] The historical aspects of cardiac dissection techniques are summarized in Supplemental File – Appendix A.

[3] The present manuscript refers to HCM as defined by the American Heart Association [AHA; Ommen et al., 2024, p. e1247): “HCM is considered a disease state in which morphologic expression is confined solely to the heart. It is characterized predominantly by LVH in the absence of another cardiac, systemic, or metabolic disease capable of producing the magnitude of hypertrophy evident in a given patient and for which a disease-causing sarcomere (or sarcomere-related) variant is identified or genetic etiology remains unresolved.”

[4] SCD as defined by the European Society of Cardiology (Zeppenfeld et al., 2022, p. 15): “Sudden natural death presumed to be of cardiac cause that occurs within 1 h of onset of symptoms in witnessed cases, and within 24 h of last being seen alive when it is unwitnessed. [SCD] in autopsied cases is defined as the natural unexpected death of unknown or cardiac cause.”

and cardiac dissection, the heart weight is an important parameter required for both diagnostic routine and pathoanatomic research (Basso et al., 2021). Expert opinions regarding the post-mortem diagnosis or analysis of myocardial hypertrophy recommend the Short-Axis method for cardiac dissection without particular consideration of the anatomical setting.

Thus, this article aims to bridge the gap between (forensic) pathological diagnosis and anatomical teaching and research. Here, we outline and discuss different cardiac dissection techniques. Furthermore, the narrative minireview explores cardiac dissection techniques that may be applied to assess myocardial hypertrophy, extending beyond standard diagnostic procedures. In addition, Supplemental File – Appendix B presents examples of cardiac dissection techniques using anatomical heart specimens. The cardiac dissection techniques discussed in the present minireview are summarized in Table 1.

2. Material and methods

The narrative minireview is based on a search of the PubMed [advanced search queries searching "All fields", 5th February 2024: (1) "(heart) AND (autopsy)", (2) "(heart) AND (dissection)", (3) "(preparation) and (heart)", (4) "(heart dissection) AND (technique)"] and Google Scholar (standard search, 5th February 2024: (1) "heart autopsy", (2) "heart dissection", (3) "preparation heart", (4) "heart dissection technique") databases. The results were non-systematically searched for dissection techniques besides those described in the aforementioned standard textbook [Armed Forces Institute of Pathology Atlas (Maleszewski et al., 2023)], focusing on the fields of myocardial hypertrophy and heart weight. Additionally, the literature was searched for further factors potentially influencing the assessed heart, such as the fixation technique applied. During the literature search, only publications reporting on dissection techniques applicable to the human heart were considered. The Google Scholar results were sorted by relevance, and the first 50 studies per search term were screened. The PubMed results were sorted by best match, and 50 articles per search term were screened.

3. Results

3.1. Disparities between (forensic) pathology and anatomy

Whole heart specimens are encountered during autopsies (e.g., anatomical dissection courses, clinical autopsies, and legal medicine case work) or after explanation from a recipient during transplant surgery (Maleszewski et al., 2023). In the pathological and legal medicine case work routine, the primary goal of the organ assessment is to achieve a diagnosis as complete and certain as possible. Correspondingly, recommendations of international societies are available on how to assess and process whole heart specimens (Stone et al., 2012). Notably, the preparation technique determines what can be seen or can be assessed, and in consequence, what can be ultimately diagnosed, as outlined by Virmani and colleagues (Virmani et al., 1987), also shown in **Supplemental File –** Supplemental Figures 1 and 2. Although several dissection techniques have been developed, not all are suitable for use in diagnostic routine (Maleszewski et al., 2023). Especially, the Short-Axis and Inflow-Outflow methods have been established for use in diagnostic routine, whereas the Short-Axis method in combination with an Inflow-Outflow-like opening of the remainder (i.e., atria and heart valves) is considered the current diagnostic standard (Basso et al., 2017; Maleszewski et al., 2023; Stone et al., 2012). Contrastingly, in the

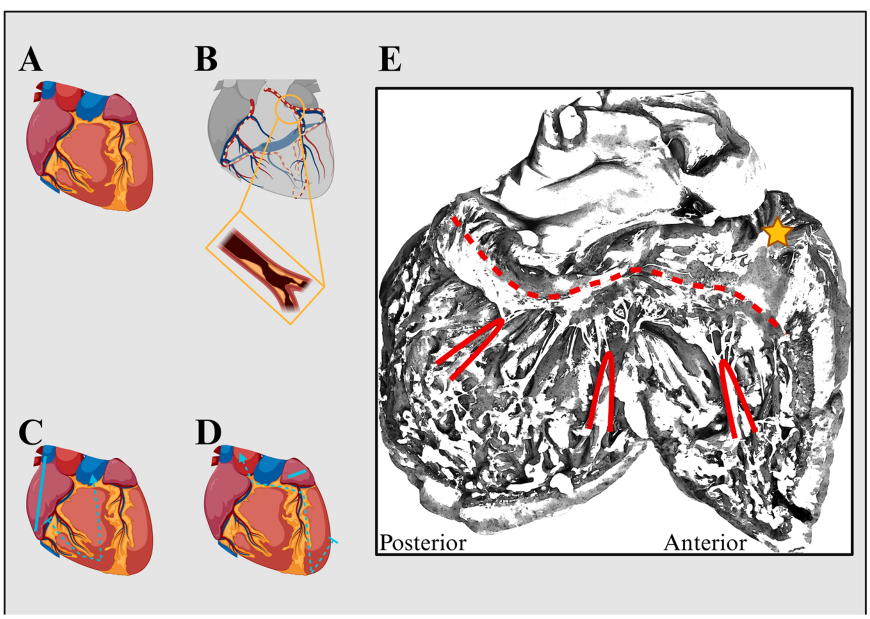

Fig. 2. Scheme Inflow-Outflow method, (A) Inspection of the heart. Trimming the large vessels. Cleaning. Inspecting the semilunar valves. (B) Longitudinal opening and detailed inspection of the coronary arteries (practical note: longitudinal opening of the coronary arteries is easy and fast but is not recommended by the recent guidelines and recommendations. Although it allows for exact determination of the length of an intramural course of a coronary artery, it does not allow for a detailed analysis of the coronary artery cross sections that facilitate a more exact description of coronary artery obstruction). (C) Posterosuperior opening of the right atrium. Cleaning. Inspection of the right atrium and tricuspid valve. Opening of the right side of the heart following the blood flow. Cleaning. Detailed inspection of the right sided heart valves, endocardium, and the inner cardiac structures. (D) Posterosuperior opening of the left atrium. Cleaning. Inspection of the left atrium and mitral valve. Opening of the left side of the heart following the blood flow. Cleaning. Detailed inspection of the left sided heart valves, endocardium, and the inner cardiac structures. (E) Schematic display of the right heart opened using the Inflow-Outflow method. The star marks the right atrial appendage. The scattered red line follows the tricuspid valve annulus. The red parabolic lines approximate the three papillary muscle complexes. Comment: Some use a section parallel to the endocardial lining in a longitudinal direction through the left ventricular wall and interventricular septum to search for focal myocardial lesions. Please note that such an approach does not allow for a detailed assessment of the distribution and topography of myocardial lesions (e.g., differentiation of subendocardial, transmural, or diffuse lesions) as claimed by recent recommendations such as (Michaud et al., 2020). In particular, early subendocardial ischemia can be overlooked in such a dissection plane. [Created in BioRender; agreement number: YX28EA82DO; figures in (Lohner et al., 2025) and (Yamasaki et al., 2024) served as paragons.].

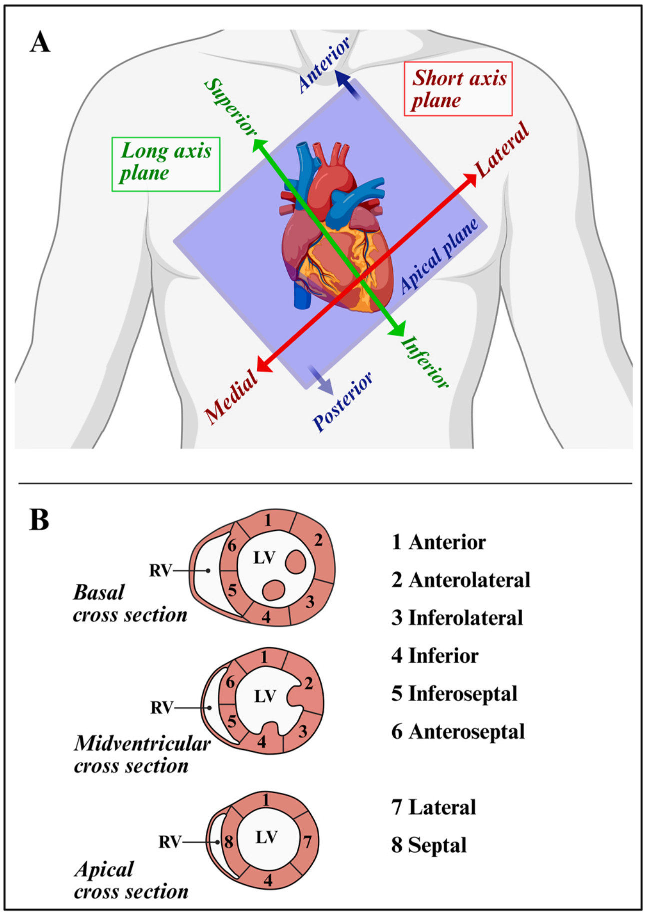

Fig. 3. Topographic designations in adult transthoracic echocardiography, (A) Topographic designations of the different scanning planes of the heart. Blue colors indicate the apical plane and related topographic designations, i.e., anterior means above the plane, and posterior refers to below the plane. Green colors show the long axis plane and related topographic designations, i.e., superior means in direction of the atria in the apical axis, and inferior means in direction of the apex in the apical axis. Red colors show the short axis plane and related topographic designations, i.e., lateral means in the direction of the left ventricle in the short axis, and medial means in the direction of the right ventricle in the short axis. (B) Nomenclature of the different myocardial segments of the left ventricle in different cross-section planes according to international recommendations (Lang et al., 2006). Created in BioRender; agreement number: HQ28EA8CIM; Fig. 1 in (Mitchell et al., 2019) served as a paragon for (A) and Fig. 1 in (Shalbaf et al., 2013) for (B).

anatomical context with a focus on research and teaching, the aim is to exemplify or display particular structures and/or conditions without necessarily taking all possible pathologies into account. This again opens a complementary spectrum of preparation techniques, which can be applied for scientific and/or educational purposes, such as the Base-of-Heart or Window methods (Maleszewski et al., 2023).

The Base-of-Heart method is of particular relevance in anatomical and pathological teaching. It starts with the application of the Short-Axis method. Second, the pulmonary trunk and the ascending aorta are transected at the height of the respective sino-tubular junction. Then, the atria are separated from the base of the heart around 1 cm above the plane of the atrioventricular valves, including the superficial half of the coronary sinus. If the epicardial fatty tissue is removed, the course of the coronaries in relation to the atrioventricular plane becomes visible. (Maleszewski et al., 2023)

The Window method is particularly suitable for teaching, especially in anatomic preparations (Edwards and Miller, 2009; Maleszewski et al., 2023). In the Window method, windows of different sizes are created using a knife in a fixed heart to visualize particular cardiac structures. The removed tissue can be used for histological analysis. (Edwards and Miller, 2009)

From a diagnostic perspective, unnecessary variation and/or combination of different dissection techniques must be avoided to ensure reproducibility (Maleszewski et al., 2023). However, in anatomic teaching, the anatomist may encounter severe dehydration and/or discoloration of the tissue because of the duration of the student course, fixation artefacts, or other post-mortem artefacts. Thus, from a practical and ethical point of view (i.e., considering the importance of each body donor), the combination of different dissection techniques can facilitate the usage of a severely and artificially hampered organ for teaching purposes. For example, the combination of the Base-of-Heart and Window methods (Fig. 4) enables the visualization of the atrioventricular valve apparatus, even in brittle and severely dehydrated hearts (**Supplemental File –** Supplemental Figure 3).

3.2. Relation of cardiac dissection, heart weight, and myocardial hypertrophy

The dissection technique and basic parameters acquired during cardiac dissection are continuously re-evaluated. Additionally, basic parameters and dissection techniques can influence each other. An outstanding example is the heart weight, which is considered an important but general indicator of cardiac pathology (Basso et al., 2021). Thus, it is constantly reassessed, for example, regarding its normal values (Holländer et al., 2020; Molina and DiMaio, 2015) or the impact of age, sex, and body size on this particular parameter (Kumar et al., 2014; Westaby et al., 2023). Reference values for total heart (fixed) weights are also available (Sheppard, 2022) referencing (Kitzman et al., 1988). Despite its seemingly undisputed importance, preparation-associated issues arise regarding this parameter. Older studies consider Fulton's technique for isolated ventricular weights (Fulton et al., 1952), the only method to confidently determine cardiac hypertrophy (Hangartner et al., 1985), even though other techniques with a particular focus on cardiac hypertrophy are available, such as the Chamber Partition technique (Bove et al., 1966).

The dissection technique published by Fulton et al. (1952) is a modified from the technique presented by Thomas Lewis [citation according to Fulton et al.: (Lewis, 1914)] and can be summarized as follows: (a) removal of the heart from the thorax; (b) inspection; (c) division of pulmonary trunk and ascending aorta approximately 1 cm above the semilunar valves; (d) posterosuperior opening of the atria; (e) washing and blood clot removal; (f) inspection of the atrioventricular valves and the inner atrial surface; (g) packing the ventricular cavities with an absorbent material (originally cotton wool); (h) immersion fixation for 72–96 h; (i) preparation of the coronary arteries; (j) exposure of the myocardium by stripping of fat and vessels by sharp dissection (k) removal of the absorbent material; (l) separation of ventricles and atria at the level of the atrioventricular rings; (m) separation of the free wall of the right ventricle with a cut in the same plane as the right ventricular surface of the interventricular septum; (n) and similar separation of the free wall of the left ventricle from the interventricular septum (Fig. 5A–D; Fulton et al., 1952).

The chamber partition technique put forward by Bove and colleagues is similar but differs in terms of the section planes, leading to a smaller sample of the interventricular septum (Fig. 5E; Bove et al., 1966).

Fulton historically described preparation with scissors (Fulton et al., 1952); however, more recent publications recommend the use of knives to avoid crushing artefacts (Maleszewski et al., 2023). If choosing the Fulton method, it is important to adhere to the recommended period for immersive fixation to avoid artificial changes of the myocardial mass and ensure comparability of the results (Fulton et al., 1952).

The Fulton technique provides a tool for determining the overall ventricular mass and separately measures the mass of the right ventricular free wall, interventricular septum, and left ventricular free wall

Table 1
Overview of different cardiac dissection techniques.

Dissection technique	Field of use	General aspects	Non-fixed hearts	Standard formalin-fixed hearts
Short-Axis method[1]	Diagnostics Research Teaching	Considered the current diagnostic standard. Well-established. Fast. Allows for detailed measurement of ventricular wall thickness. Fine-grained assessment of potential coronary obstructions. Allows for a detailed assessment of the size and shape of the ventricular cavities. Fast and easy standardized sampling for subsequent histological analyses.	Easily applicable	Easily applicable
Inflow-Outflow method[2]	Diagnostics Research Teaching	May be considered for diagnostic routine. Well-established. Fast. Allows for swift sequential analysis of the heart and assessment of congenital malformations such as atrioventricular and ventriculoarterial discordance (i.e., double discordance or congenitally corrected transposition of the heart arteries).	Easily applicable	Dehydration and hardening of the tissue can hamper the application of the method.
Chamber Partition technique[3]	Research	Targeted approach for the detailed assessment of the myocardial mass. Applicable for research purposes. Time-consuming. May be applied only to fixed hearts.	Not applicable	Requires 72–96 h of fixation
Fulton technique[4]	Research (Diagnostics)	Targeted approach for the detailed assessment of the ventricular myocardial mass; for this particular issue considered the best technique. Applicable for research and in the diagnosis of pre-selected individual cases in which the exact myocardial mass and the exact distribution of myocardial hypertrophy are of particular diagnostic importance. Time-consuming. May be applied only to fixed hearts.	Not applicable	Requires 24–48 h of fixation
Window method[2]	Teaching	Targeted visualization of particular (intra-)cardiac structures. Not applicable for diagnostic routine. Particularly useful for anatomical preparations. The tissue excised to create the window can be used for histological analyses.	May be difficult in limp and soft tissues.	Easily applicable, even in hard, brittle, and dehydrated samples.
Base-of-Heart method[2]	Teaching Research	Specific and detailed visualization of the heart valves and the parts of the fibrous skeleton of the heart located at the base of the heart. May be time-consuming. Useful for research and teaching.	May be difficult in limp and soft tissues.	Fixation makes application of the technique easier due to tissue hardening.
Combination of different dissection techniques[4]	Teaching	Not applicable for the diagnostic routine. Can facilitate the usage of a severely artificially altered sample for (research and/or) teaching.	Depends on the combined methods.	Depends on the combined methods.

Table 1. Summary of the authors' experience (i.e., in anatomy, pathology, and legal medicine) with various cardiac dissection techniques discussed in the minireview for the diagnostic routine, research, and teaching. Although older publications describe the usage of scissors for opening and dissecting the heart (e.g., Fulton et al., 1952), nowadays, it is avoided, and a knife is used to avoid crushing artefacts (e.g., Maleszewski et al., 2023). ***Annotations:*** 1 as recommended in international guidelines and recommendations (Basso et al., 2017; Stone et al., 2012), see Fig. 1 and **Supplemental File –** Supplemental Figure 2; 2 as described by a standard textbook for cardiovascular pathology (Maleszewski et al., 2023) or a handbook of autopsy practice (Edwards and Miller, 2009), see Fig. 2 and **Supplemental File –** Supplemental Figure 1; 3 as published by Bove et al. (1966), see Fig. 4; 4 as described by Fulton and co-workers (Fulton et al., 1952), see Fig. 4; 4 see **Supplemental File –** Supplemental Figure 3;

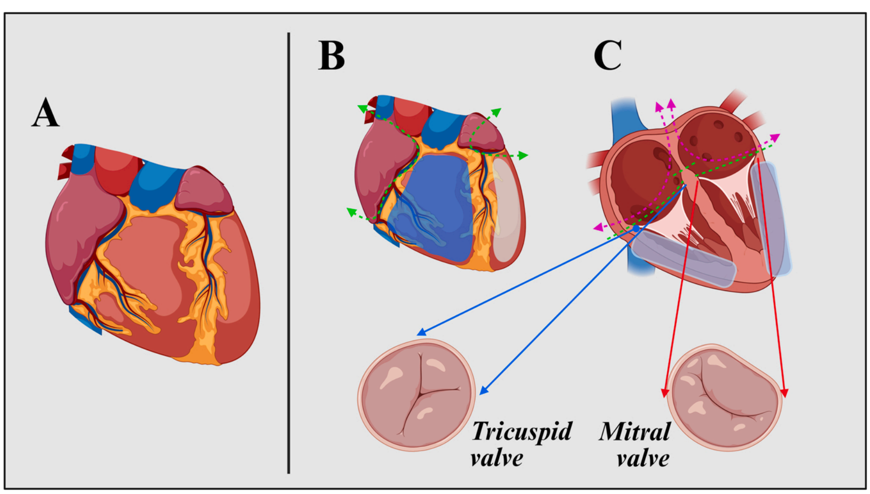

Fig. 4. Scheme Base-of-Heart and Window methods, The Base-of-Heart method aims to visualize the plane of the fibrous skeleton of the heart, and the semilunar and atrioventricular valves. It is usually applied to the basal remainder of the heart following laminating cross sections through the ventricles instead of the opening following the blood flow, as in the standard Short-Axis method. (Maleszewski et al., 2023) (A) Trimming of the large vessels. Cleaning. Inspection of the semilunar valves. (B and C) Sharp dissection of the atrial myocardium close to the rings of the atrioventricular valves. Comment: For anatomical teaching, the Base-of-Heart method can be combined with the Window method (hood-like removal of the free wall of each ventricle while sparing the papillary muscles, as shown by the translucent rectangular shapes). This combination allows for a detailed display of the atrioventricular valves, including the subvalvular apparatus. For a detailed description, see 3.1. Case example shown in **Supplemental File –** Supplemental Figure 3. [Created in BioRender; agreement number: OH28EA8MGB; descriptions by (Edwards and Miller, 2009; Maleszewski et al., 2023) served as paragons.].

(Fulton et al., 1952). Thus, the actual distribution of myocardial hypertrophy can be captured with this technique. The distribution of myocardial hypertrophy is an important diagnostic hint regarding the underlying cause of myocardial hypertrophic remodeling (Federspiel et al., 2024a). However, the Fulton technique is no longer discussed in recent forensic pathological studies regarding heart weight (Holländer

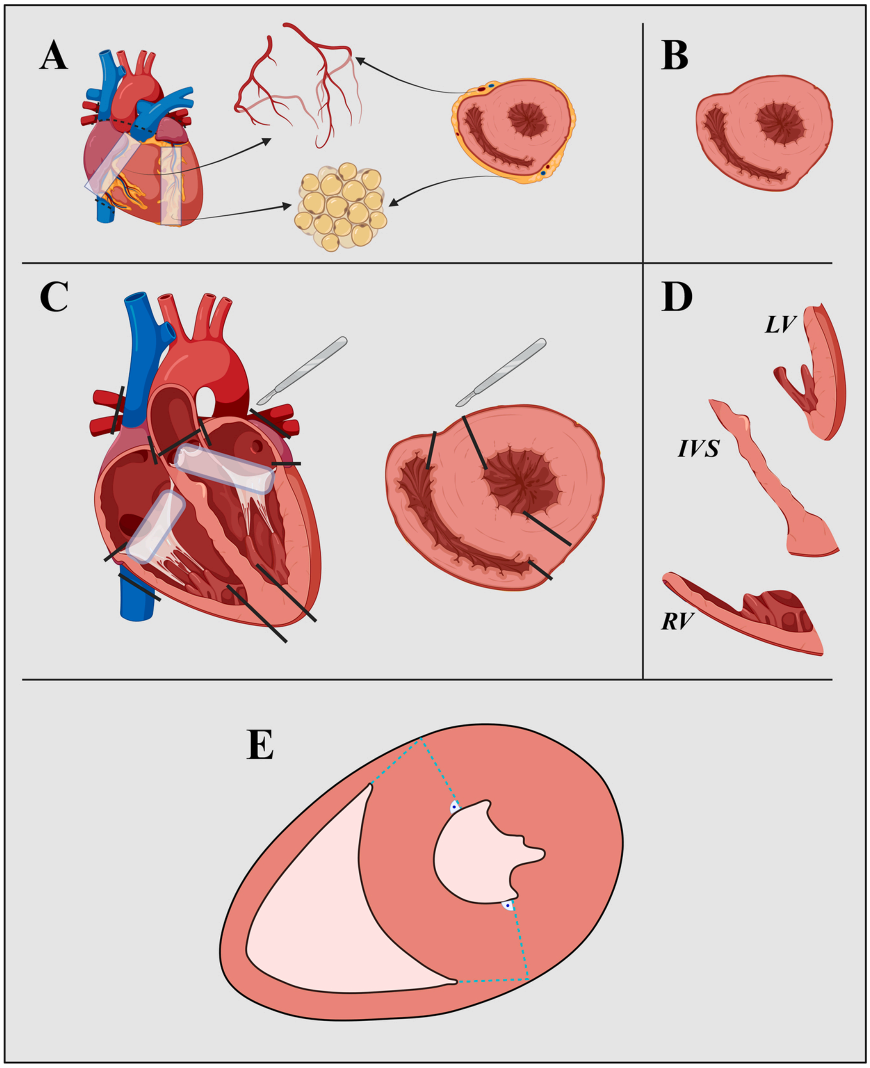

Fig. 5. Scheme Fulton and Chamber Partition methods, The Fulton and Chamber Partition methods can be applied to fixed hearts. For a detailed description, see 3.2. (A) Removal of the epicardial fatty tissue and the epicardial coronary vessels using a sharp dissection to (B) expose the myocardial outer surface. (C) The left ventricular free wall and the right ventricular free wall are separated from the interventricular septum after removal of the atria. The heart valves are also excised. (D) The Fulton method produces three separate myocardial specimens: left ventricular free wall, right ventricular free wall, and the interventricular septum. These samples can be weighed separately for an in-depth analysis of myocardial hypertrophy and its distribution. (E) The Chamber Partition technique uses different dissection planes (bright blue dotted lines) from the Fulton technique. Created in BioRender; agreement number: IY28EA8Y0S; the original publications describing these techniques Bove et al., 1966; Fulton et al., 1952) served as paragons.

et al., 2020; Kumar et al., 2014; Westaby et al., 2023) or in current recommendations (Basso et al., 2017; Kelly et al., 2023; Stone et al., 2012) and standard textbooks (Maleszewski et al., 2023). This apparent recession in relevance is contrasted by the fact that fixing the heart and removing epicardial fatty tissue before determining the heart weight is a standard procedure in student-teaching, as it allows visualization of the coronary arteries. One reason for the heterogeneity of approaches to evaluate the same parameter (in this instance, the heart weight) in different settings (anatomy vs. diagnostic routine; past vs. present) might be the time needed for intricate preparation procedures like the Fulton technique or the removal of epicardial fat. In this regard, recent pathological and highly differential studies on heart-weight determination, such as (Westaby et al., 2023), could be complemented by an anatomical approach. Such an interdisciplinary synopsis could contribute to a more precise understanding of heart morphology and heart weight, with the Fulton procedure providing the most accurate information (Hangartner et al., 1985) and thus might better support the diagnostics than conventional determination of the heart weight alone.

4. Discussion

Three aspects of cardiac dissection require consideration: (a) what the researcher/clinician would like to see or analyze, (b) what the researcher/clinician wants to do with the organ or tissue samples later on, and (c) the conclusions the researcher/clinician would like to draw. The answers to these three questions determine the choice of fixation procedure. For example, different preservation methods are available: the organ can undergo formalin fixation (Eckner et al., 1969), glutaraldehyde can be applied to fix particular structures, such as heart valves (Christie et al., 1992) and coronary arteries (Choy et al., 2005), or “whole-mount” paraffin embedding can be applied to congenitally malformed hearts (Rosenberg and Marcontell, 1964). Different applications of the fixation medium can be performed, e.g., perfusion-fixation (Thomas and Davies, 1985) or immersion-fixation (Gross and Leslie, 1931). The interference of the chosen fixation approach with different morphological and morphometrical findings must be considered. This includes its microscopic (De Souza et al., 2004) as well as macroscopic findings (Eckner et al., 1969), which influence the morphological and morphometrical assessment of the heart. Additionally, the heart weight can be influenced by the fixation technique (Fulton et al., 1952). Furthermore, different analyses of cardiac tissue, if done subsequently, can also interfere with each other, as demonstrated for protein analyses following laser microdissection (De Souza et al., 2004). Concerning the strengths and weaknesses of the various currently prevailing dissection procedures (Table 1), great potential lies in the development of methods related to the dissection of the heart itself. For example, different perfusion approaches can foster the diagnostic power of the macroscopic assessment (Federspiel et al., 2022) or improve sampling for subsequent histological analyses (Lux et al., 2022). Also, casts of the ventricular cavities could facilitate further structural investigations of the heart (Kilner et al., 1989).

4.1. Peculiarities of cardiac dissection in an anatomical framework

The anatomical framework holds particular special features. In our experience, a high proportion of people donating their bodies for post-mortem use in research and education includes chronically ill and elderly individuals (Abdinghoff et al., 2022; Federspiel et al., 2023; Jacobs et al., 2022; Walz et al., 2023). This selection bias must be taken into consideration while conducting any research utilizing tissue from body donors. Furthermore, samples derived from body donors can hardly serve as a reference group or control without further investigation to prove their suitability as a reference cohort. This especially holds true for the heart because of the high prevalence of cardiovascular diseases in the general population (Mensah et al., 2019).

4.2. Cardiac hypertrophy in a subject-specific context

In the forensic and clinical pathology setting, the diagnosis of an increased heart weight can point toward underlying pathologies such as genetic disorders (e.g., HCM), which may require complementary examinations beyond the post-mortem scope. According to the current state of knowledge, genetic causes can be identified in approximately 60 % of patients with HCM, thus calling for clinical assessment and genetic testing of biological relatives with the aim of individual risk stratification and prevention of (further) SCD events in affected families (Arbelo et al., 2023; Marian and Braunwald, 2017). The correct collection and interpretation of the heart weight is therefore paramount in routine pathology case work. However, heart weight is a variable measure, influenced by body height, body weight, age, and sex, and should therefore always be assessed with respect to these parameters. In recent years, several publications have addressed the topic of heart-weight assessment, leading to the development of user-friendly online tools for application in routine autopsy practice of unfixed hearts (Schoppen et al., 2020; Vanhaebost et al., 2014; Wingren and Ottosson, 2015). Such tools calculate the predicted normal (i.e., healthy, heart weight range) of an individual, which can then be compared to the actual heart weight measured at autopsy. Clinical guidelines cite left ventricular wall thickness at one site $\geq$ 15 mm as a diagnostic criterion for HCM (13–14 mm in case of known familial disease) (Arbelo et al., 2023). In the clinical setting, these measurements are performed using imaging techniques, whereas in the post-mortem setting, they are routinely collected by direct measurement of the ventricular wall thickness. The Short-Axis method of dissection is ideally suited for this purpose, especially because it also allows for measurement of the interventricular septum thickness with ease. However, care must be taken to accurately perform the ventricular sections in parallel to the base plane to capture the true wall thickness and to avoid skewed results because of sloped cuts (Maleszewski et al., 2023).

In view of the genetic and preventive background outlined above, the gross examination of a hypertrophic heart can provide important diagnostic hints regarding the underlying disease leading to myocardial thickening. For example, concentric left ventricular remodeling and concentric left ventricular hypertrophy are two typical findings in hypertensive cardiomyopathy (Ganau et al., 1992). While gross patterns can easily be assessed using the Short-Axis method, this method does not sufficiently analyze finer details of ventricular geometry. One example of its limitation is the assessment of the shape of the interventricular septum (Binder et al., 2006). In terms of septal shape, the sigmoid septum, reverse-curved septum, apical hypertrophy, and neutral shape can be distinguished (Binder et al., 2006); for example, using a topographic dissection method displaying a four-chamber view, mirroring the clinical setting (Maleszewski et al., 2023). Considering the importance of genetic testing for the prevention of SCD, a sigmoid septum (i.e., a S-shaped septum with prominent curvature into the left ventricular outflow tract) is rarely associated with a sarcomeric or sarcomere-associated mutation, whereas the majority of patients with a reverse-curved septum (i.e., septal mass curving into the midventricular portion of the left ventricular cavity) show such a mutation (Binder et al., 2006). Although the Short-Axis method does not enable a finely grained assessment of septal shape, it allows adequate sampling of specimens to be used for subsequent analyses, especially histology, and in accordance with current guidelines (Basso et al., 2017; Stone et al., 2012). These are crucial to further assess the underlying cause of myocardial hypertrophy.

In terms of microscopic anatomy, a rather non-specific finding consistently associated with thickened myocardium is the cardiomyocyte disarray (Hughes, 2004). However, during histological assessment of hypertrophic myocardium, the sampling site always has to be considered (Hughes, 2004). For example, an interlacing cardiomyocyte disarray in the basal interventricular septum can also be observed in normal hearts (Hughes, 2004; St John Sutton et al., 1980), possibly because of the interlacing of both ventricles.

4.3. Quality control of cardiac dissection

Autopsy is the cornerstone of sampling for histological assessment (Basso et al., 2017; Stone et al., 2012) and is considered the current gold standard for the determination of the cause of death (Aase, 2013). Peer review of the autopsy results is fundamental for diagnostic routine quality (Obenson and Wright, 2013). Interestingly, despite the importance of the cardiac dissection, little is known regarding the inter- and intra-rater reliability of the cardiac autopsy. The authors were able to identify only a single recent study on the reliability of the digital measurements of cardiac dimensions in photographs that considered different training statuses (Gadsby et al., 2025). However, the anatomist has the best chances to get the most experience in non-standard cardiac dissection techniques owing to the particular feature of the anatomical setting. In other words, the anatomist is most likely to achieve reliable results in an anatomic research series. In contrast, pathologists and legal medicine experts are likely to develop their expertise in the standardized cardiac dissection methods recommended for the diagnostic routine, i.e., the Short-Axis and Inflow-Outflow methods. From the experience of the authors, anatomists and pathologists more frequently dissect formalin-fixated hearts compared to legal medicine experts.

5. Conclusion

Various cardiac dissection techniques, some of which are outside current recommendations, enable the in-depth assessment of myocardial hypertrophy and heart weight. Regardless of the subject (i.e., anatomy, pathology, or legal medicine) and the setting (i.e., diagnostic routine, research, or teaching), the desired endpoint (e.g., assessment of particular structures or sampling for subsequent analysis) and case characteristics (e.g., HCM and/or congenital malformation) determine the appropriate cardiac dissection technique. Anatomists can generally apply a broader spectrum of techniques compared to pathologists and legal medicine experts, who are required to follow international recommendations and to meet diagnostic standards to uphold reliable diagnoses in routine case work. For anatomical teaching, the simultaneous display of several dissection techniques improves visualization of distinct anatomic structures and supports a better understanding of topographic cardiac anatomy. In pathoanatomical research on cardiovascular diseases, specific dissection techniques beyond those employed in diagnostic routines offer advantages in improving the understanding of myocardial hypertrophy and heart weight (e.g., Fulton method).

CRediT authorship contribution statement

Federspiel Jan Michael: Writing – review & editing, Writing – original draft, Visualization, Investigation, Conceptualization. **Peter H. Schmidt:** Writing – review & editing, Resources. **Eva Corvest:** Writing – review & editing. **Johannes E. Hohneck:** Writing – review & editing. **Carola Meier:** Writing – review & editing, Validation, Supervision, Resources, Conceptualization.

Ethical approval and consent to participate

According to the local ethical committee case reports do not require an ethical vote. Body donors provided their written informed consent during their lifetime for the post-mortem use of their body for research and teaching purposes.

Declaration of Generative AI and AI-assisted technologies in the writing process

No generative AI has been used for the preparation of the present manuscript.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aanat.2025.152711.

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