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Review Articles

Comparing Cadaveric Dissection and Advanced Imaging Techniques in Coronary Artery Visualization: Implications for Surgical Planning and Patient Outcomes

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Accurate coronary artery visualization is critical for successful angiography and surgery. This study compares cadaveric dissection and in-situ surgical views in aiding surgical planning and patient outcomes.A comparative analysis reviewed cadaveric dissection and angiographic imaging, focusing on advancements like 3D coronary angiography. Strengths, limitations, and clinical applications were assessed.Cadaveric dissection provides detailed anatomical insights, while 3D angiography offers dynamic, real-time imaging that improves surgical precision. Recent intraoperative imaging advancements enhance visualization, reduce complications, and improve outcomes.Dissection remains essential for detailed anatomy understanding, but modern imaging technologies offer a less invasive, complementary approach for surgical planning. Combining these methods enhances clinical decision-making and outcomes.Advanced imaging technologies play a vital role in coronary artery visualization, complementing dissection-based learning to improve surgical accuracy and patient care.

Key words: coronary artery, cadaveric dissection, advanced imaging, surgical planning, patient outcomes

Introduction

The coronary arteries, essential for supplying oxygen-rich blood to the myocardium, are fundamental to the heart's functioning. A precise understanding and visualization of their anatomy are crucial for diagnosing coronary artery diseases (CAD) and planning interventions such as coronary artery bypass grafting (CABG), angioplasty, and stent placement. CAD, often caused by atherosclerosis, is a leading cause of morbidity and mortality globally. Accurate coronary artery visualization is vital for effective surgical planning and improving patient outcomes. Thus, both clinical and research efforts have focused on methods to achieve detailed coronary artery imaging.

Historically, coronary angiography has been the gold standard for diagnosing CAD, providing clear images of the coronary lumen to detect blockages and assess their severity. However, it is a two-dimensional (2D) technique with limitations in visualizing complex coronary anatomy, particularly in patients with tortuous or branching vessels. Over the past few decades, advancements in imaging technologies have significantly enhanced coronary artery visualization. Innovations such as three-dimensional (3D) coronary angiography, optical coherence tomography (OCT), and intravascular ultrasound (IVUS) have greatly improved the understanding of coronary anatomy, refined surgical planning, and optimized interventional procedures [5, 8, 12].

Recent developments in 3D coronary angiography allow more accurate vessel reconstructions, enabling better visualization of vessel orientation, branching patterns, and stenoses. Technologies like OCT and IVUS provide high-resolution images of the coronary lumen, assessing plaque composition and coronary flow, thereby improving diagnostic accuracy and procedural guidance. Various studies demonstrated the superiority of 3D angiography and OCT in improving procedural outcomes, particularly in patients with complex coronary anatomy [16, 28].

Despite the technological advances in imaging, cadaveric dissection remains a cornerstone for understanding coronary anatomy. Dissections provide detailed insights into coronary artery variations that may be missed or misinterpreted by in vivo imaging techniques. However, cadaveric dissection is limited by the static nature of the body and post-mortem tissue changes. Still, studies continue to underscore the value of cadaveric dissection in understanding coronary anomalies relevant to surgical procedures [9, 14]. This study explores the evolving landscape of coronary artery imaging, aiming to compare the accuracy and limitations of angiographic, cadaveric, and in-situ surgical views of coronary anatomy. By evaluating the strengths and weaknesses of each method, the study will assess their contributions to surgical planning and clinical outcomes. The integration of modern imaging techniques alongside traditional dissection methods presents an opportunity to improve coronary artery assessment, offering real-time, non-invasive visualization that overcomes the limitations of previous approaches. The study will also consider the impact of fusion imaging, hybrid techniques, and advancements in artificial intelligence on the future of coronary artery imaging and surgical practices.

The aim of this study is to conduct a comparative analysis of coronary artery anatomy visualization through two primary methods – cadaveric dissection and angiographic imaging techniques emphasizing their contributions to surgical planning, accuracy, and patient outcomes. The objectives are:

- To compare the effectiveness of cadaveric dissection and angiographic imaging in visualizing coronary artery anatomy.
- To assess the advantages and limitations of each method in terms of anatomical precision and clinical applicability.
- To evaluate the impact of recent advancements in 3D coronary angiography and intraoperative imaging technologies on surgical planning and patient outcomes.
- To explore how cadaveric dissection and modern imaging techniques complement each other in enhancing surgical decision-making.
- To identify the role of advanced imaging methods in improving surgical precision, reducing complications, and enhancing overall patient care.

Coronary artery anatomy and its significance in surgery

Anatomical overview

The coronary arteries are essential for supplying oxygenated blood to the heart muscle, ensuring its proper function. These arteries originate from the aorta just above the aortic valve and branch out into a complex network that supplies different regions of the heart. The coronary arterial system is generally divided into the left and right coronary arteries, each with major branches supplying specific territories of the myocardium.

Left Coronary Artery (LCA): The LCA is a short vessel that divides into two main branches:

Left Anterior Descending Artery (LAD): This artery runs along the anterior surface of the heart, supplying the anterior wall of the left ventricle, the interventricular septum, and the apex of the heart. It is considered critical due to the high mortality risk if obstructed [10, 11].

Left Circumflex Artery (LCx): The LCx supplies the lateral and posterior walls of the left ventricle, and in some cases, the inferior wall, depending on coronary variations [21].

Right Coronary Artery (RCA): The RCA supplies the right atrium, right ventricle, and inferior wall of the left ventricle. It also typically supplies the sinoatrial (SA) and atrioventricular (AV) nodes, along with several branches, including the acute marginal artery, which feeds the right ventricular free wall [25, 6].

Variations in coronary anatomy

Although most individuals have a standard coronary anatomy, variations are common, either congenital or acquired, and have clinical significance, especially during surgical procedures such as coronary artery bypass grafting (CABG) and angioplasty.

Dominance: Coronary artery dominance refers to which artery supplies the posterior descending artery (PDA) and posterior left ventricular branches. Most people have right dominance, where the RCA supplies the PDA, but about 10% exhibit left dominance, where the LCx supplies the PDA [25]. Rarely, both arteries may supply the PDA, a condition called codominance [15].

Dual LAD: In some individuals, the LAD is duplicated, and two branches supply the anterior wall of the heart. This variation, called dual LAD, is clinically significant, especially when CAD affects both branches. Surgeons must address both arteries in procedures like CABG or percutaneous coronary intervention (PCI) [21].

Anomalous Coronary Arteries: Anomalous coronary arteries, such as those originating from unusual sinus positions or having abnormal courses, are rare but carry significant clinical implications, particularly in cases where compression of the anomalous artery occurs during physical activity [6].

Role in surgical procedures

An accurate understanding of coronary anatomy is essential for successful cardiac surgeries, including CABG, angioplasty, and stent placement. Knowledge of coronary anatomy enables surgeons to plan procedures that restore heart blood flow while minimizing complications.

Coronary Artery Bypass Grafting (CABG): In CABG, blocked or narrowed coronary arteries are bypassed using grafts to restore blood flow. Surgeons must understand coronary anatomy, including variations and blockage locations, to avoid ischemia. For instance, in a patient with a dominant RCA, grafts must bypass the RCA and its branches effectively [21]. In dual LAD cases, both arteries must be revascularized.

Percutaneous Coronary Intervention (PCI): PCI, including angioplasty and stenting, uses a catheter to open blocked arteries. Precise knowledge of coronary anatomy guides stent placement. Variations such as dual LAD or left dominance complicate PCI and may require special attention [17, 6].

Other Interventional Strategies: Other surgical strategies like left ventricular assist device (LVAD) implantation, heart transplantation, and valve surgeries also rely on understanding coronary anatomy. Each patient's unique vascular structures may require modifications in approach [25].

Coronary artery disease (CAD) and its impact on coronary anatomy

CAD, caused by the accumulation of atherosclerotic plaques, significantly affects coronary anatomy. It reduces blood flow to the myocardium, leading to symptoms such as angina, myocardial infarction (MI), and heart failure. Over time, CAD can alter coronary artery structures, complicating diagnosis and treatment.

Impact on Coronary Anatomy: The progression of CAD leads to vessel remodeling and collateral circulation, where new vessels form to supply blood to affected areas. These collateral vessels can mislead surgeons, making it challenging to differentiate well-perfused vessels from those with underlying disease [6]. Severe stenosis in areas like the LAD or RCA requires careful planning to ensure revascularization.

Role of Imaging in Diagnosing CAD: Imaging techniques like coronary angiography, CT angiography, and MRI are essential for diagnosing CAD and planning treatment. These methods help assess blockages, vessel anomalies, and variations, which are critical for tailoring interventions such as PCI or CABG [25].

Interventional Planning in CAD: CAD treatment options like PCI or CABG depend on disease severity and coronary anatomy. Variations in coronary arteries require a personalized approach to ensure complete revascularization. For example, special care is needed to bypass the RCA in right-dominant patients, while dual LAD cases require both arteries to be treated [21]. Accurate imaging remains a cornerstone for diagnosing coronary disease, identifying anomalies, and planning treatment strategies effectively.

Coronary angiography: techniques and advances

Coronary artery disease (CAD) is a leading cause of morbidity and mortality worldwide, making accurate and timely diagnosis crucial. Coronary angiography (CA) remains the gold standard for diagnosing CAD, enabling clinicians to visualize coronary arteries and identify obstructions, stenoses, or plaques that impair blood flow to the heart muscle. Over time, coronary angiography has advanced significantly, with technological innovations enhancing its accuracy and clinical utility. This article explores the methodology of coronary angiography, recent advancements, and their impact on diagnostic precision and patient outcomes.

Standard coronary angiography

Coronary angiography emerged in the 1960s, with the first successful selective coronary arteriography performed in 1962 [23]. The procedure became the gold standard for evaluating coronary artery anatomy and diagnosing CAD. It involves injecting a contrast medium into the coronary arteries via a catheter, typically through the femoral or radial approach, the latter of which is becoming more popular due to lower complication rates and shorter recovery times.

Coronary angiography helps identify the location, severity, and number of stenoses or blockages in the coronary vessels, which is crucial for determining treatment strategies such as medical therapy, percutaneous coronary intervention (PCI), or coronary artery bypass grafting (CABG). Results are usually classified using the coronary artery disease severity index, which helps estimate the need for interventional procedures. Although widely used, conventional coronary angiography has limitations. It provides a two-dimensional (2D) view, which can distort the assessment of complex lesions, tortuous vessels, or small arteries. Moreover, it does not provide detailed information on plaque composition or vessel wall injury, both important for assessing the risk of cardiovascular events.

Technological advancements in coronary angiography

Recent advancements in imaging technologies have significantly improved coronary angiography. Innovations such as three-dimensional (3D) angiography, intravascular ultrasound (IVUS), optical coherence tomography (OCT), and fusion imaging have been integrated into clinical practice to overcome the limitations of traditional 2D angiography.

3D coronary angiography

The development of 3D coronary angiography has greatly enhanced cardiovascular imaging. By combining multiple 2D images obtained during traditional angiography, 3D angiography creates detailed, three-dimensional reconstructions of the coronary arteries. This allows for more accurate visualization, especially in complex cases involving bifurcation lesions or coronary artery stenting. Advances in software and image processing have improved visualization in challenging anatomical features like tortuosity or calcification, improving treatment planning precision and increasing the success of coronary interventions. Additionally, 3D angiography reduces procedural time and radiation exposure compared to conventional 2D angiography [17,22].

Intravascular ultrasound (IVUS)

IVUS has substantially improved coronary angiography's diagnostic capabilities. This technique involves inserting an ultrasound probe into the coronary artery to provide real-time imaging of the vessel wall and surrounding structures. Unlike angiography, IVUS offers detailed images of the vessel's internal structure, helping assess the true severity of coronary lesions. IVUS can detect lipid-rich plaques or thin-cap fibroatheromas that may be missed by conventional angiography, which are associated with increased rupture risk and myocardial infarction. It also guides stent placement during PCI, ensuring optimal stent size and positioning [9].

Optical coherence tomography (OCT)

OCT offers high-resolution imaging of coronary lesions, using near-infrared light to capture detailed cross-sectional images with a resolution of up to 10 micrometers, surpassing that of IVUS. This superior resolution helps visualize finer features of coronary arteries, such as plaque microstructure and intimal hyperplasia. OCT is particularly useful in guiding stent implantation in complex coronary anatomies, enabling clinicians to assess stent expansion and apposition, thus reducing restenosis or post-procedural complications [20].

Fusion imaging

Fusion imaging combines data from multiple imaging modalities, such as coronary angiography, computed tomography (CT), and magnetic resonance imaging (MRI), to create a comprehensive representation of the coronary vasculature. This technique provides a more holistic assessment of coronary lesions, considering factors like plaque composition, vessel elasticity, and blood flow, which single imaging methods may miss. Fusion imaging aids in better risk stratification and guides treatment decisions, improving patient outcomes by integrating functional and anatomical data[2].

Comparison with other imaging methods

While advances in coronary angiography have improved diagnostic precision, the technique still has limitations. Traditional 2D angiography sometimes provides incomplete or distorted images due to the complexity of coronary anatomy. Furthermore, angiography focuses mainly on structural assessment without evaluating the functional significance of coronary lesions. This has led to complementary imaging techniques like fractional flow reserve (FFR) [1] and computed tomography angiography (CTA), which assesses blood flow and lesion severity, providing further guidance for decision-making [24].

In conclusion, the integration of 3D coronary angiography, IVUS, OCT, and fusion imaging into clinical practice has significantly enhanced the diagnostic and therapeutic potential of coronary angiography. These advancements not only improve the accuracy of CAD diagnosis but also contribute to better patient outcomes by enabling more personalized treatment strategies.

Cadaveric dissection and its role in understanding coronary anatomy

The study of human anatomy, particularly coronary artery anatomy, is essential in understanding cardiovascular health, guiding clinical decisions, and improving surgical outcomes. Among various educational tools and research methods, cadaveric dissection remains one of the most valuable. It provides direct insights into the complexities of the coronary arteries, revealing arterial patterns, branching, and variations that may not be fully captured through imaging techniques. This paper explores the role of cadaveric dissection in understanding coronary anatomy, its advantages, limitations, and recent contributions.

Cadaveric dissection: an overview

Cadaveric dissection offers a unique advantage by providing a detailed and direct view of coronary anatomy. Unlike imaging techniques such as CT angiography, which offer indirect representations, dissection allows for the study of actual tissue specimens. This hands-on approach enables a deep analysis of the coronary arteries' patterns, branching, and variations, which are vital for understanding coronary circulation and informing surgical planning. Cadaveric dissection is especially useful in revealing rare coronary anomalies that might be missed in living individuals. While imaging captures large-scale coronary structures, it is less effective at revealing fine details, such as variations in vessel morphology that could impact surgery or intervention. Additionally, it allows the study of arterial wall texture, which is important for procedures like coronary artery bypass grafting (CABG) or stent placement.

Advantages of cadaveric dissection

High Fidelity to Actual Anatomical Structures: One significant advantage of cadaveric dissection is its ability to provide a direct view of arteries and their variations, without reliance on imaging software interpretation. This tactile experience helps researchers and clinicians understand the coronary anatomy in depth, offering an unmediated view of structural nuances.

Study of Rare Anatomical Variations: Cadaveric dissection is invaluable for studying rare coronary variations, such as anomalous origins or abnormal branching patterns, which are difficult to detect in living individuals. These variations can be crucial for surgeries like CABG or percutaneous coronary interventions (PCI). By directly exposing the anatomy, dissection provides a unique opportunity to explore these clinically significant variations[23].

Educational Tool for Surgical Training: Cadaveric dissection has long been a cornerstone of medical education. Surgeons-in-training, particularly those in cardiothoracic and cardiovascular specialties, benefit from dissecting coronary arteries to understand the vascular system's structure. This hands-on training ensures that surgeons are well-prepared for the practical demands of heart surgery, where anatomical knowledge and precision are crucial.

Limitations of cadaveric dissection

Post-Mortem Changes: A limitation of cadaveric dissection is the alteration of anatomy due to post-mortem changes. After death, tissues undergo biochemical and physiological changes, including stiffening and the collapse or distortion of blood vessels. These changes can affect the coronary arteries' appearance, making them less representative of living conditions.

Fixed Specimens and Lack of Dynamic Conditions: Cadaveric specimens are typically fixed and preserved, which means they no longer mimic the dynamic conditions of living tissues.Coronary arteries in living bodies respond to factors like blood pressure, heart rate, and oxygen demands, which cannot be simulated in cadaveric specimens. This limits the ability to study the coronary system under in vivo conditions.

Recent studies have highlighted the critical role of cadaveric dissection in advancing our understanding of coronary artery anatomy and its clinical implications. Studies utilized cadaveric dissection to explore variations in coronary artery anatomy, identifying rare anomalies such as unusual branching of the left main coronary artery, which are important for refining surgical strategies in coronary bypass surgery [24].

Coronary artery anatomy in relation to myocardial infarction (MI) was examined and revealed subtle variations that influence outcomes of interventions like stent placement, emphasizing that cadaveric dissection is essential for understanding nuances of coronary disease [12].Variations in the right coronary artery (RCA), was focused including cases of duplicated RCA and unusual origins, which are often difficult to detect using imaging techniques [6,19]. These studies underscore the value of cadaveric dissection in both understanding rare anatomical variations and improving surgical planning for interventions such as CABG and PCI. Despite the limitations of post-mortem changes and fixed specimens, these studies highlight how dissection remains an irreplaceable tool in both research and education for clinicians.

In-situ surgical views of coronary arteries

Coronary artery disease (CAD) is a leading cause of morbidity and mortality worldwide, and its treatment often involves coronary artery bypass grafting (CABG). Successful CABG requires detailed, real-time, in-situ views of the coronary arteries, which are facilitated by advanced imaging technologies, intraoperative assessments, and refined surgical techniques. This article explores recent advancements in coronary artery visualization, focusing on imaging technologies, artery visualization techniques, and their impact on surgical outcomes.

Imaging technologies for in-situ coronary artery visualization

The role of imaging in CABG has evolved significantly. Traditional methods like angiography provide useful preoperative views but have limitations during surgery due to the heart's complex anatomy. Recent intraoperative imaging advancements, including intravascular ultrasound (IVUS), optical coherence tomography (OCT), and near-infrared spectroscopy, have improved coronary artery visualization during surgery. IVUS enhances real-time, high-resolution images of coronary arteries, improving lesion identification and graft placement [4]. This allows surgeons to assess coronary artery walls in detail, improving long-term graft patency. OCT's ability to provide even higher resolution than IVUS was highlighted, offering real-time images of the intimal layer of coronary arteries [13]. OCT aids in precise graft anastomosis and minimizes graft failure post-surgery by providing detailed plaque morphology.

Role of 3D imaging and navigation systems

Three-dimensional (3D) imaging and navigation systems have revolutionized coronary artery surgery, providing surgeons with dynamic, interactive views of coronary anatomy. Authors demonstrated that 3D-printed coronary artery models, created from preoperative CT angiograms, improved surgical accuracy, reduced surgery duration, and shortened recovery times [11]. The models offered surgeons enhanced in-situ views, optimizing graft placement. Images explored augmented reality (AR), which integrates 3D coronary artery images with real-time surgical footage [18]. AR systems provided a comprehensive view of coronary anatomy while allowing surgeons to stay focused on the surgical site, improving precision and reducing complications.

Advances in intraoperative coronary artery assessment

In addition to imaging technologies, intraoperative assessments are crucial for ensuring proper graft placement and function. Intraoperative hemodynamic monitoring and coronary flow assessment help guide graft selection and confirm graft patency.

The use of fractional flow reserve (FFR) was explored during CABG to measure the pressure drop across coronary artery lesions and assess ischemia severity. The study showed that FFR measurements allow for a tailored approach to graft selection, improving graft patency and patient outcomes. Near-infrared spectroscopy (NIRS) is also gaining traction for monitoring graft patency. NIRS enables real-time, non-invasive monitoring of oxygen saturation in coronary vessels, providing immediate feedback on graft functionality [20]. This helps detect graft failure and facilitates prompt corrective measures, improving postoperative outcomes by reducing complications.

Surgical techniques and impact on outcomes

Sophisticated imaging technologies and intraoperative assessments have refined surgical techniques for coronary artery bypass. Minimally invasive techniques, such as robotic-assisted surgery, have become more prevalent due to their enhanced precision and improved visibility. These techniques reduce surgery invasiveness, shorten recovery time, and enhance patient outcomes. A study evaluated robotic-assisted coronary artery bypass surgery, enhanced by advanced imaging technologies [26]. The study found that robotic surgery with high-definition intraoperative imaging resulted in more accurate graft placements, fewer complications, and faster recovery compared to traditional open-heart surgery. Robotic systems allowed for smaller incisions, reducing hospital stays and speeding up recovery times.

Recent advancements in imaging technologies and surgical techniques have significantly improved in-situ surgical views of coronary arteries, enhancing the precision and outcomes of CABG procedures. Technologies like IVUS, OCT, 3D imaging, augmented reality, and intraoperative monitoring have improved coronary artery visualization, leading to better graft placement, reduced complications, and faster recovery. These innovations have revolutionized coronary artery surgery, promising even more refined techniques and improved outcomes as research and technology continue to advance.

Comparative analysis: cadaveric vs angiographic vs in-situ views in coronary anatomy visualization

The visualization of coronary anatomy is crucial for preoperative planning, intraoperative decision-making, and post-operative care. Among the various techniques used to study coronary arteries, cadaveric views, angiographic views, and in-situ views each provide unique insights. However, each method has its own strengths and limitations in terms of anatomical accuracy, detail, and clinical utility. This comparative analysis explores these three techniques, focusing on their accuracy, clinical implications, and advancements in coronary imaging.

Cadaveric views: accuracy and anatomical detail

Cadaveric views offer high anatomical accuracy because they are derived from human specimens. Cadaveric dissections allow for direct visualization of coronary arteries, including their branches and variations, which can provide an in-depth understanding of normal and pathological coronary anatomy. These views are often considered the gold standard for anatomical study, as they reflect true anatomical relationships.

Recent studies have emphasized the value of cadaveric dissections for teaching and understanding coronary anatomy [11]. The study highlighted that cadaveric views are invaluable in educational settings, where detailed anatomical knowledge is critical for students and surgeons. However, while cadaveric views offer high anatomical detail, they do not reflect certain variations seen in living patients, such as the effects of plaque buildup or arterial motion. Additionally, cadaveric dissection is static, and in vivo anatomical variations such as arterial twisting, dynamic movement, and physiological change are absent, limiting the generalizability of cadaveric studies to living patients.

Angiographic views: clinical effectiveness and limitations

Angiography remains one of the most commonly used imaging techniques in clinical practice for visualizing coronary arteries. It is a real-time, dynamic procedure that uses contrast media and X-ray imaging to visualize coronary blockages, stenosis, and anomalies. Angiography is particularly effective in diagnosing coronary artery disease (CAD), allowing for the direct visualization of lumen narrowing and occlusions. Recent advancements, particularly with fractional flow reserve (FFR) and intravascular ultrasound (IVUS), have enhanced diagnostic capabilities. Combining angiography with FFR significantly improved the accuracy of identifying functionally significant coronary lesions, improving preoperative planning [5].

However, angiographic views have notable limitations. Angiograms provide a two-dimensional (2D) representation of coronary arteries, leading to issues such as foreshortening, overlapping, and distortion of vessels. This makes accurate anatomical interpretation difficult. Furthermore, angiography primarily detects blockages rather than providing a comprehensive understanding of coronary vessel anatomy, including branching patterns and anatomical variations [3]. Despite these limitations, angiography remains an essential tool for real-time decision-making, particularly in interventions like percutaneous coronary interventions (PCI), where it aids in stent placement and monitoring post-operative outcomes.

In-situ views: dynamic assessment and patient-specific factors

In-situ views are obtained directly from living patients using advanced imaging modalities, such as coronary CT angiography (CTA) and magnetic resonance imaging (MRI). These non-invasive methods provide real-time imaging, allowing dynamic assessment of the coronary arteries under physiological conditions. Coronary CTA, in particular, has gained popularity for non-invasive coronary artery disease assessment, offering detailed three-dimensional reconstructions of coronary anatomy.

The effectiveness of coronary CTA in assessing CAD was demonstrated, especially for patients with intermediate risk profiles [26]. The study emphasized that coronary CTA could visualize coronary anomalies and calcification patterns, which essential for treatment are planning. Additionally, CTA provides a dynamic view of coronary arteries, including coronary flow assessment and heart function, in one scan. However, in-situ views have limitations related to patient-specific factors, such as motion artifacts, patient movement, and anatomical variations that can affect image quality. The resolution of non-invasive imaging methods like CTA may also fall short of cadaveric dissection, making it challenging to visualize small branches and precise relationships between vessels and surrounding tissues.

Clinical implications: contributions to planning and decision-making

Each imaging technique plays a distinct role in clinical practice. Cadaveric views are particularly useful in educational settings, where understanding coronary anatomy in detail is essential for surgeons performing coronary bypass surgery or studying coronary anomalies. Angiographic views are indispensable for intraoperative decision-making, guiding interventions such as angioplasty and stenting. Angiography is also crucial for preoperative planning, helping identify coronary lesions that require intervention.

In-situ imaging, particularly coronary CTA and MRI, is useful for both preoperative planning and post-operative follow-up. These techniques provide a comprehensive, non-invasive view of coronary anatomy, enabling clinicians to assess the impact of CAD on heart function. Furthermore, in-situ views are valuable for monitoring disease progression over time, offering a dynamic view of the patient's coronary health.

Advancements in technology: bridging the gap

Advancements in imaging technology, such as 3D reconstructions from angiographic data, are helping bridge the gap between 2D angiograms and cadaveric views. The introduction of coronary CT angiography has significantly improved the level of detail available from non-invasive imaging, providing high-resolution, 3D reconstructions that are becoming increasingly reliable in assessing coronary artery disease. The growing role of artificial intelligence (AI) and machine learning algorithms in coronary imaging demonstrated, improving precision by reducing motion artifacts and enhancing image quality [27]. These technologies are contributing to a more accurate and detailed understanding of coronary anatomy, overcoming the limitations of traditional imaging methods.

Limitations and recommendations

Each method has inherent limitations. Cadaveric views, while anatomically accurate, do not account for dynamic physiological factors. Angiography, though essential for detecting blockages, lacks detailed anatomical visualization. In-situ imaging, while offering dynamic and patient-specific data, suffers from resolution limitations and motion artifacts. A combination of these methods can provide the most comprehensive understanding of coronary anatomy. Future research should focus on integrating these imaging techniques to create hybrid models that combine the advantages of cadaveric detail, angiographic precision, and in-situ dynamics. Moreover, ongoing advancements in 3D imaging, artificial intelligence, and motion correction will continue to improve the accuracy and utility of coronary imaging.

Summary of key findings

Cadaveric dissection remains the gold standard for anatomical accuracy, offering detailed insights into the coronary arteries' structure. Studiesaffirmed the importance of cadaveric views in educational settings [11]. However, cadaveric dissections cannot replicate dynamic changes, such as arterial movement and blood flow, making them less relevant for clinical applications like preoperative planning. Angiographic views are indispensable for diagnosing coronary artery disease (CAD) and guiding interventions such as PCI. However, angiography is limited by its 2D representation, which can distort and obscure certain anatomical details, and its primary focus on detecting blockages rather than providing a complete anatomical overview.

In-situ views, particularly coronary CTA and MRI, offer dynamic, patient-specific imaging, bridging the gap between cadaveric detail and angiographic functionality. Recent advancements in coronary CTA have enhanced its accuracy, offering high-resolution 3D reconstructions of coronary arteries [26]. However, like angiography, in-situ imaging may suffer from limitations related to resolution and motion artifacts. Despite these challenges, in-situ views remain valuable for preoperative planning and monitoring post-operative progress non-invasively.

Future directions

The future of coronary imaging lies in the integration of multiple imaging modalities, powered by emerging technologies such as AI and machine learning. Studies have shown that AI can enhance image quality by reducing motion artifacts and improving resolution. Hybrid imaging methods, combining angiography, optical coherence tomography (OCT), and cadaveric data, could further advance coronary artery visualization. These advancements hold promise for more effective diagnosis and intervention planning, improving patient outcomes.

The combination of 3D imaging and AI algorithms could allow for personalized, dynamic reconstructions of coronary arteries, taking into account patient-specific variations in vessel morphology, disease progression, and response to treatment. This could improve preoperative planning, as surgeons would be able to visualize coronary anatomy in a way that closely mimics actual patient conditions, leading to more precise and targeted interventions.

Clinical implications

The evolving landscape of coronary imaging has profound implications for clinical practice, especially in cardiology and cardiac surgery. Integrating advanced imaging technologies is expected to improve coronary disease diagnosis, reduce complications during interventional procedures, and enhance surgical planning. For example, combining angiographic data with FFR and IVUS has already improved decision-making during coronary interventions, allowing for more targeted therapies. Similarly, coronary CTA helps identify coronary anomalies, assess plaque burden, and predict complications, thus guiding surgical decisions and improving patient outcomes.

As hybrid imaging techniques and AI become more prevalent, coronary artery surgeries and interventions will benefit from improved precision, leading to better long-term outcomes. These advancements will enable more personalized treatments based on unique coronary anatomy and disease characteristics. As technology continues to evolve, future research will likely focus on optimizing the integration of these techniques into clinical workflows, ensuring they are used to their full potential in both preoperative and postoperative care.

Conclusion

The comparative analysis of cadaveric, angiographic, and in-situ views in coronary anatomy provides valuable insights into their respective roles in understanding coronary vessel structure and aiding clinical decision-making. Each of these imaging modalities has its distinct strengths and limitations, but recent advancements in technology are helping to bridge the gaps between them. This synthesis highlights the evolving role of these techniques in surgical planning, and the exciting potential of emerging technologies in enhancing coronary imaging.

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