Enhancing Surgical Precision with Intraoperative Angiography: Real-time Visualization in Vascular and Neurosurgical Procedures

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Test and Answers

Multiple Choice Test: Intraoperative Angiography

1. [ ] What is the primary purpose of intraoperative angiography?
    1. [ ] To monitor the patient's vital signs during surgery.
    2. [x] To provide real-time visualization of blood vessels during surgery.
    3. [ ] To administer anesthesia to the patient.
    4. [ ] To remove blood clots from the bloodstream.

1. [ ] Which imaging equipment is commonly used for intraoperative angiography?
    1. [ ] Magnetic resonance imaging (MRI)
    2. [ ] Ultrasound machine
    3. [x] C-arm fluoroscopy machine
    4. [ ] Electrocardiogram (ECG) machine

1. [ ] How does intraoperative angiography contribute to surgical outcomes?
    1. [ ] It speeds up the surgery.
    2. [x] It reduces the need for postoperative physical therapy.
    3. [x] It allows for immediate assessment and intervention, reducing complications.
    4. [ ] It eliminates the need for contrast dye injection.

1. [ ] Which access site options are mentioned for intraoperative angiography?
    1. [ ] Transverse thoracic access
    2. [x] Transfemoral, transradial, and transulnar access
    3. [ ] Transcatheter aortic access
    4. [ ] Transcranial access

1. [ ] What is the significance of using transradial and transulnar access sites for neuro-interventional procedures?
    1. [ ] They are more cost-effective.
    2. [ ] They provide better image quality.
    3. [x] They are safer and preferred by patients.
    4. [ ] They are only suitable for cardiac procedures.

1. [ ] In which patient positions can intraoperative angiography be safely performed?
    1. [ ] Supine position only

    2. [x] Prone, three-quarters prone, and park-bench positions
    3. [ ] Sitting position
    4. [ ] Lateral decubitus position

1. [ ] What are the indications for using intraoperative angiography?
    1. [ ] Diagnosis of diabetes
    2. [x] Aneurysm surgery and arteriovenous malformation surgery
    3. [ ] Orthopedic surgery
    4. [ ] Cosmetic surgery

1. [ ] Which contrast agent can be used for intraoperative angiography to visualize surface vessels?
    1. [ ] Iodinated contrast
    2. [ ] Gadolinium
    3. [ ] Barium sulfate
    4. [x] Indocyanine green

1. [ ] What is the main advantage of intraoperative digital subtraction angiography (ioDSA) in neurovascular procedures?
    1. [ ] It has a lower cost.
    2. [ ] It has a higher availability.
    3. [x] It is highly efficient and has a low risk of complications.
    4. [ ] It is suitable for all patients.

1. [ ] Why might ioDSA be best suited for selected patients with complex neurovascular pathologies?
    1. [ ] Due to its lower cost and higher availability.
    2. [ ] Because it eliminates the need for other imaging modalities.
    3. [ ] Because it is faster than other angiography techniques.
    4. [x] Because it can potentially detect perfusion rests and remnants, leading to changes in the surgical strategy.

Abstract

Intraoperative angiography is a valuable medical imaging technique used in vascular and neurosurgical procedures to provide real-time visualization of blood vessels. It involves the injection of contrast dye into the bloodstream and the use of specialized imaging equipment, such as C-arm fluoroscopy machines. Intraoperative angiography allows for immediate assessment of blood vessels, detection of abnormalities, and on-the-spot interventions to ensure optimal blood flow. It offers real-time feedback to surgical teams, reducing postoperative complications and improving surgical outcomes. The choice of access site, whether transfemoral, transradial, or transulnar, is influenced by safety and patient satisfaction considerations. Studies have shown that these alternative access sites are safe and effective for neuro-interventional procedures. Furthermore, the use of intraoperative angiography in various patient positions, such as prone or park-bench, has been found to be feasible and safe, with a notable rate of surgical adjustment/revision. Indications for intraoperative angiography include aneurysm surgery and arteriovenous malformation surgery, with options for contrast agents including traditional iodinated contrast and indocyanine green. The value of intraoperative angiography is particularly evident when used in combination with other imaging modalities, such as indocyanine green videoangiography. A risk-benefit analysis has shown that intraoperative digital subtraction angiography (ioDSA) is efficient, with low complication rates. IoDSA can potentially detect perfusion rests and remnants, leading to changes in the surgical strategy.

However, due to its higher costs and lower availability compared to indocyanine green angiography, ioDSA may be best suited for selected patients with complex neurovascular pathologies.*

Overall, intraoperative angiography is a powerful tool that enhances surgical procedures, improves patient outcomes, and contributes to the safety and efficacy of neurovascular surgeries.

Keywords: Intraoperative angiography, medical imaging, real-time visualization, vascular surgery, neurosurgery, contrast dye, imaging equipment, real-time assessment, complications, outcomes, access, transfemoral approach, transradial access, transulnar access, safety, efficacy, prone position, indocyanine green, arteriovenous malformation, aneurysm, arteriovenous fistula, surgical microscope, robotic c-arm, risk-benefit analysis.

Introduction

Intraoperative angiography is a medical imaging technique that is performed during surgery to visualize blood vessels in real time. It is particularly useful in various surgical procedures, especially those involving vascular surgery and neurosurgery. The goal of intraoperative angiography is to assess the patency, location, and integrity of blood vessels and make necessary adjustments or corrections during the surgical procedure.

Here's how intraoperative angiography works:

Preparation: Before the surgery, the patient may be prepared by injecting a contrast dye into the bloodstream. This dye helps to make the blood vessels more visible on X-ray or fluoroscopy images.

Imaging Equipment: During the surgery, the surgeon uses specialized imaging equipment such as a C-arm fluoroscopy machine or a mobile angiography unit. The C-arm is a movable X-ray machine that can be positioned over the surgical area to capture real-time images.

Real-Time Imaging: The surgeon or a radiologic technologist can take X-ray images or perform fluoroscopy (continuous X-ray imaging) to visualize the blood vessels. The contrast dye in the bloodstream makes the vessels stand out on the images.

Assessment: Intraoperative angiography allows the surgeon to assess the blood flow, detect any obstructions or abnormalities, and ensure that the surgical procedure is proceeding as planned. For example, in vascular surgery, it can help identify stenoses (narrowing of blood vessels) or blockages.

Intervention: If a problem is identified, such as a blockage or aneurysm, the surgeon can take immediate corrective action, such as placing stents, removing clots, or reshaping blood vessels.

Confirmation: After the necessary adjustments or repairs have been made, another round of angiography is performed to confirm that the blood vessels are functioning properly. This step is crucial for assessing the success of the surgical procedure.

Intraoperative angiography has several advantages:

Real-time assessment: It provides immediate feedback to the surgical team, allowing them to adjust their actions as needed. Minimized complications: Identifying and addressing issues during surgery

can reduce the risk of postoperative complications. Improved outcomes: Ensuring optimal blood flow can lead to better surgical outcomes, especially in procedures involving critical organs or vascular structures. However, it's important to note that the use of X-ray radiation and contrast dye carries some inherent risks, so the benefits of intraoperative angiography must be carefully weighed against potential risks, and the procedure should be performed by skilled professionals with appropriate safety measures in place.

Access

Historically, the transfemoral approach (TFA) has been the most common access site for cerebral intraoperative angiography (IOA). However, in line with trends in cardiac interventional vascular access preferences, the transradial access (TRA) and transulnar access (TUA) have been gaining popularity owing to favorable safety and patient satisfaction outcomes.

Tudor et al. compared the efficacy and safety of TRA/TUA and TFA for cerebral and spinal IOA at an institutional level over a 6-year period.

Methods: Between July 2016 and December 2022, 317 angiograms were included in our analysis, comprising 60 TRA, 10 TUA, 243 TFA, and 4 transpopliteal approach cases. Fluoroscopy time, contrast dose, reference air kerma, and dose-area products per target vessel catheterized were primary endpoints. Multivariate regression analyses were conducted to evaluate predictors of elevated contrast dose and radiation exposure and to assess time trends in access site selection.

Results: Contrast dose and radiation exposure metrics per vessel catheterized were not significantly different between access site groups when controlling for patient position, operative region, 3D rotational angiography use, and different operators. Access site was not a significant independent predictor of elevated radiation exposure or contrast dose. There was a significant relationship between case number and operative indication over the study period ($P<0.001$), with a decrease in the proportion of cases for aneurysm treatment offset by increases in total cases for the management of arteriovenous malformation, AVF, and moyamoya disease.

TRA and TUA are safe and effective access site options for neuro-interventional procedures that are increasingly used for IOA [1].

Reviews

Vivanco-Suarez et al reviewed (between January 1960 and July 2022) all studies in which IOAs were performed during neurosurgical procedures with patients in either prone, three-quarters prone, or park-bench positions. Additionally, a cohort of patients from self-institutional experience was included. Efficacy outcomes were the rate of successful angiography and the rate of surgical adjustment/revision after IOA. Safety outcomes were the rate of angiography-related complications and mortality. Data were analyzed using a random-effects meta-analysis of proportions, and statistical heterogeneity was assessed.

A total of 26 studies with 142 patients plus 32 subjects from their own institutions were included in the analysis. The rate of successful intraoperative angiography was 98% (95% CI 94% to 99%; I2=0%). The rate of surgical adjustment/revision was 18% (95% CI 12% to 28%; I2=0%). The rate of complications related to the angiography was 1% (95% CI 0% to 5%; I2=0%). There were no deaths

associated with IOA.

They found that IOA performed with patients in prone, three-quarters prone, and park-bench positions is feasible and safe with a non-negligible rate of intraoperative post-angiographical surgical adjustment/revision. The findings suggest that the performance of IOA to complement vascular neurosurgical procedures might have a valuable role in favoring patient outcomes [2].

Indications

Typically used in aneurysm surgery to confirm exclusion of the aneurysm from the circulation and to verify patency of critical adjacent vessels, and during AVM surgery to confirm total elimination of the nidus.

1. using traditional iodinated contrast and fluoroscopy. Requires use of Radiolucent Head Frame. Typically the introducer sheath is placed in the femoral artery at the time of initial pre-op angio, and is left in place for intraoperative use.

2. indocyanine green (ICG) [3] [4] : can be visualized under normal light, or sometimes to better advantage when illuminated with near-infrared light. Use is restricted to surface vessels. May be less reliable with giant or wide necked aneurysms or with thick walled atherosclerotic.

Among the different arterial accesses, the femoral access is the main approach for intraoperative angiography (IOA) performed in a prone position. Without a standardized protocol, however, the application of prone IOAs in intracranial arteriovenous malformation (AVM) or arteriovenous fistula (AVF) surgery remains limited by its procedural complexity [5].

Surgical microscope-integrated intraoperative angiography with intravenous injection of indocyanine green (ICG) has been widely used during bypass or aneurysm surgery. Instead of intravenous injection of ICG.

The value of intraoperative angiography in the time of indocyanine green videoangiography

Intraoperative digital subtraction angiography (ioDSA) allows early treatment evaluation after neurovascular procedures. However, the value and efficiency of this procedure has been discussed controversially. Durner et al. from Günzburg, evaluated the additional value of hybrid operating room equipped with an Artis Zeego robotic c-arm regarding cost, efficiency and workflow. Furthermore, they performed a risk-benefit analysis and compared it with indocyanine green videoangiography.

For 3 consecutive years, they examined all neurovascular patients, treated in the hybrid operating theater in a risk-benefit analysis. After using microdoppler and ICG angiography for best operative result, every patient received an additional ioDSA to look for remnants or unfavorable clip placement which might lead to a change of operating strategy or results. Furthermore, a workflow-analysis

reviewing operating steps, staff positioning, costs, technical errors or complications were conducted on randomly selected cases.

54 patients were enrolled in the risk-benefit analysis, 22 in the workflow analysis. The average duration of a cerebrovascular operation was 4 h 58 min 2 min 35 s accounted for ICG angiography, 46 min 4 s for ioDSA. Adverse events occurred during one ioDSA. In risk-benefit analysis, ioDSA was able to detect a perfusion rest in 2 out of 43 cases (4,7%) of aneurysm surgery, which could not have been visualized by ICG angiography before. In arterio-venous-malformation (AVM) surgery, one of 11 examined patients (7,7%) showed a remnant in ioDSA and resulted in additional resection. The average cost of an ioDSA in Ulm University can be estimated with 1928,00€.

According to the results ioDSA associated complications are low. Relevant findings in ioDSA can potentially avoid additional intervention, however, due to the high costs and lower availability, the main advantage might lie in the treatment of selected patients with complexes neurovascular pathologies since ICG angiography is equally safe but associated with lower costs and better availability [6].

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