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CASE REPORT

Intraoperative use of indocyanine green fluorescence angiography to determine amputation level: A case report

Uso intraoperatorio de angiografía por fluorescencia con verde indocianina para definir nivel de amputación: Reporte de un caso

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Abstract

Introduction: Indocyanine green (ICG) angiography has been widely adopted in several medical areas. Given that it allows real-time visualization of blood perfusion and tissue irrigation, its intraoperative utilization may be useful to determine amputation level in patients presenting with diabetic angiopathy or occlusive peripheral artery disease.
Case presentation: A 70-year-old female patient with a significant medical history, including right transtibial amputation due to complications secondary to diabetic microangiopathy, was admitted to the intensive care unit (ICU) of a quaternary care center of Bogotá D.C. (Colombia) after her clinical condition was stabilized following an acute myocardial infarction without ST-segment elevation. On admission to the ICU, an ulcerated lesion with signs of necrosis was observed in the left heel, requiring computed tomography angiography (CT angiography). Based on CT angiography findings, cardiovascular involvement, and the presence of poor-quality vascular beds, the vascular surgery service concluded that she was not a candidate for endovascular treatment and, together with the prosthetics and amputee service, it was decided that transfemoral amputation was the most appropriate option. During surgery, ICG angiography showed adequate perfusion in the proximal third of the leg, so a transtibial amputation was carried out, considering that this level of amputation has benefits in terms of functional rehabilitation and general quality of life.
Conclusion: The intraoperative use of ICG angiography as a complementary tool to determine amputation level made it possible to preserve the greatest amount of viable tissue in our patient. This likely contributed to reducing the risk of postoperative complications, since she did not experience any adverse events and did not require reoperation. Furthermore, this approach led to a decrease in the costs associated with the treatment. However, studies with larger samples are required to confirm its efficacy in this clinical setting.
Keywords: Surgical Amputation; Indocyanine Green; Peripheral Arterial Disease; Diabetic Angiopathies; Case Reports (MeSH).

Resumen

Introducción. La angiografía por fluorescencia con verde indocianina ha sido ampliamente utilizada en varias áreas médicas. Dado que permite la visualización en tiempo real de la perfusión sanguínea y de la irrigación de los tejidos, su uso intraoperatorio puede ser útil para definir el nivel de amputación en pacientes con esta indicación debido a angiopatía diabética o enfermedad arterial oclusiva.
Presentación del caso. Mujer de 70 años con múltiples antecedentes de relevancia, incluyendo una amputación transtibial derecha por complicaciones secundarias a microangiopatía diabética, quién, una vez estabilizada su condición clínica después de sufrir un infarto agudo de miocardio sin elevación del ST, fue ingresada a la unidad de cuidados intensivos (UCI) de un hospital de cuarto nivel en Bogotá D.C. (Colombia). Al ingreso a la UCI se observó lesión ulcerada con signos de necrosis en el talón izquierdo, por lo que realizó una angiotomografía computarizada (angioTAC). Con base en los hallazgos de la angioTAC, el compromiso cardiovascular y la presencia de lechos vasculares de mala calidad, el servicio de cirugía vascular determinó que no era candidata para manejo endovascular y, junto con el servicio de prótesis y amputados, se decidió que la amputación transfemoral era la opción de manejo más adecuada. Sin embargo, durante la cirugía, mediante angiografía por fluorescencia con verde indocianina se observó una adecuada perfusión en el tercio proximal de la pierna, por lo cual se decidió realizar una amputación transtibial, con las ventajas que este nivel de amputación implica para la rehabilitación funcional y la calidad de vida general.
Conclusión. El uso intraoperatorio de la angiografía por fluorescencia con verde indocianina como herramienta complementaria para definir el nivel de amputación permitió preservar la mayor cantidad de tejido viable en nuestra paciente, lo que probablemente contribuyó a reducir el riesgo de complicaciones postoperatorias, ya que no presentó eventos adversos ni requirió reintervenciones. Esto, a su vez, implicó una reducción de los costos asociados al tratamiento. No obstante, se requieren estudios con muestras más grandes para confirmar su utilidad en este escenario clínico.
Palabras clave: Amputación Quirúrgica; Verde de Indocianina; Enfermedad Arterial Periférica; Angiopatías Diabéticas; Informes de casos (DeCS).

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Introduction

Objectively establishing the level of amputation in patients with an indication for lower extremity amputation due to peripheral vascular disease is particularly critical, since their rehabilitation and reintegration, both into society and the labor market, depend on this decision.[1] Currently, various methods are available for this purpose, including arteriography,[2] computed tomography angiography (CT angiography),[3] and transcutaneous oximetry,[4] although the latter is not accessible in most Colombian institutions.

Indocyanine green is a water-soluble tricarbocyanine compound capable of absorbing near infrared light (at a wavelength of approximately 750 to 800nm) and re-emitting it as fluorescence (at an approximate wavelength of 830nm).[5] It is administered intravenously and its rapid and extensive binding to plasma proteins ensures its confinement in the intravascular compartment with little leakage to the interstitium, making it an ideal fluorophore for use in angiography. It also has a good patient safety profile, as it has no toxic or ionizing metabolites, being metabolized by the liver within 3-5 minutes after injection and excreted in bile.[5] Given these characteristics, indocyanine green (ICG) angiography is a test that allows real-time assessment of microvascular and macrovascular systems for surgical purposes such as amputation.[6]

ICG angiography has been widely used in various medical areas for decades; however, the literature on its use in orthopedics is sparse.[7] This technique provides a new alternative for defining the level of amputation, as it allows for an accurate assessment of blood flow in soft tissues as well as peripheral vessels close to the skin.[3] Moreover, its use during surgery makes it possible to corroborate whether the amputation level chosen during surgical planning is adequate, as well as to identify and correct sutures that could potentially lead to irrigation interruption, thus preventing the development of residual limb necrosis and other complications.[3]

The following is the case of an elderly woman who underwent transtibial amputation of the left limb due to diabetic foot and in whom ICG angiography was used intraoperatively to establish the amputation level, obtaining satisfactory outcomes.

Case presentation

A 70-year-old female patient was taken to the emergency department of a quaternary care hospital in Bogotá D.C. (Colombia) after suffering from acute myocardial infarction without ST-segment elevation and was admitted to the intensive care unit (ICU) once stable. The patient presented with glaucoma, type 2 diabetes mellitus, arterial hypertension, chronic obstructive pulmonary disease, chronic renal disease, dilated cardiomyopathy (left ventricular ejection fraction of 40%), and multivessel coronary artery disease, which required catheterization and angioplasty with implantation of three stents in 2022, with CHA2DS2- VASc score of 5, indicating paroxysmal chronic atrial fibrillation. The patient had also undergone multiple lower limb vascular bypasses due to peripheral arterial disease (the last one being performed in August 2022), as well as right leg amputation below the knee and left lower limb transmetatarsal amputation due to diabetic foot. On admission to the ICU, a 5x6cm ulcerated lesion with signs of necrosis was observed in the posterior region of the left heel (Figure 1).

Figure 1. Large, ulcerated lesion (5x6 cm) with signs of necrosis on the left foot on admission to the ICU.
Source: Image obtained while treating the patient.

On the first day of ICU stay, the patient was assessed by specialists from the vascular surgery service, who requested a CT angiography of the lower limbs performed on the same day. The following was found: severe atherosclerosis and arterial tortuosity in left lower limb involving the abdominal aorta, iliac arteries, deep femoral artery, and popliteal artery; occlusion of the distal third of the left femoral artery (where it crosses the adductor canal) and occlusion of the middle third of the deep femoral artery; recanalization of the left popliteal artery through collateral arteries with stenosis >75%; occlusion of the proximal third of the left peroneal artery; occlusion of the proximal third of the left posterior tibial artery; and occlusion of the right popliteal and deep femoral (proximal third) arteries with evidence of blood flow in muscles of the proximal third of the leg. Given these findings, the patient's cardiovascular involvement, and the presence of poor quality distal vascular beds (confirmed by the hemodynamics service), the vascular surgery service concluded that the patient was not a candidate for endovascular management with angioplasty of the popliteal artery, so they requested an assessment of the patient by specialists from the prosthetics and amputee service, which decided that left transfemoral amputation was the best management option.

On the fifth day of hospital stay, the patient was taken to the operating room for amputation. Approximately 30 minutes prior to the procedure, 0.25mg of ICG (0.1cc of a 10mL vial containing 2.5 mg/mL) was administered through venous access (right radial vein). Distal perfusion of the left leg was assessed intraoperatively using ICG angiography and the SPY elite system, which has built-in quantification software that can quantify the image data captured by the near-infrared camera.[8] Since adequate perfusion was observed in the soft tissues of the proximal third of the leg (Figure 2), it was decided that transtibial amputation was the best option. In addition, to obtain the flap to cover the amputation stump, an incision was made anteriorly at the junction of the proximal and middle third of the leg and posteriorly at 12cm from the joint space.

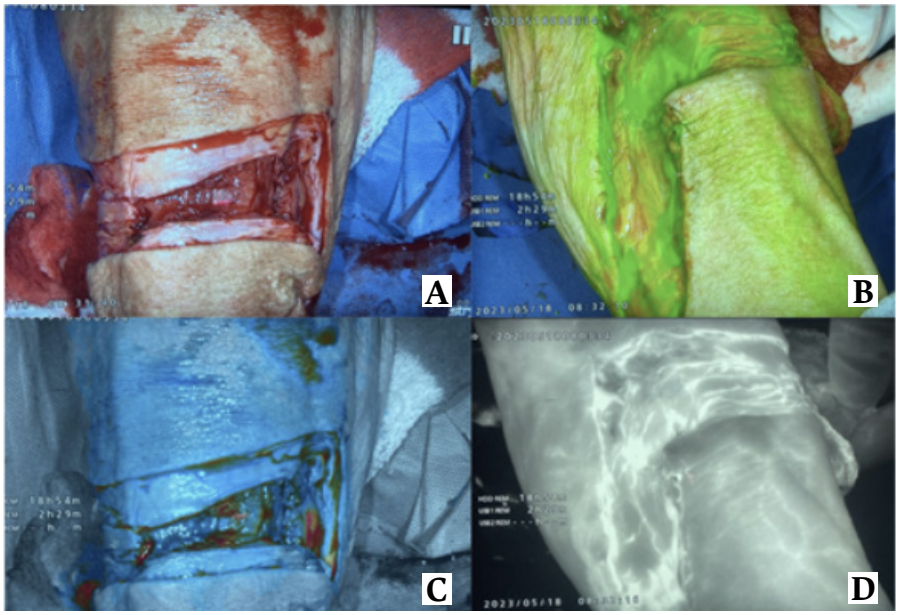

Figure 2. Intraoperative visualization of blood flow in the proximal middle third of the left lower limb (ICG fluorescence) using the SPY elite system. **A.** White light image. **B.** Overlay mode: the fluorescence image (green) is displayed over a 1080p white light image. **C.** Color-segmented fluorescence mode: increasing fluorescence intensities go first from blue to yellow and then to red. **D.** Contrast mode (fluorescence image is displayed in grayscale): fluorescence is observed in the flap to be used for amputation stump coverage, as well as in the surrounding muscle tissues.
Source: Images obtained while treating the patient.

Once the amputation level was defined and the flap was obtained, the anterior and lateral compartments were dissected to identify the sural, posterior tibial, and peroneal neurovascular bundles, which were ligated with a silk tie. Then, using a Gigli saw, the tibia and fibula (the latter 2cm above the tibial cut) were cut in a posterior to anterior trajectory; the edges of the bones were smoothed using a bone rasp. At this point, a new evaluation of distal perfusion was made using ICG (administered prior to the procedure; Figure 3). Once it was confirmed that it was adequate, a layered closure was performed, starting with the closure of the subcutaneous tissue with 2-0 vicryl (separate stitches) and then the skin with 3-0 prolene (separate stitches). There were no intraoperative complications.

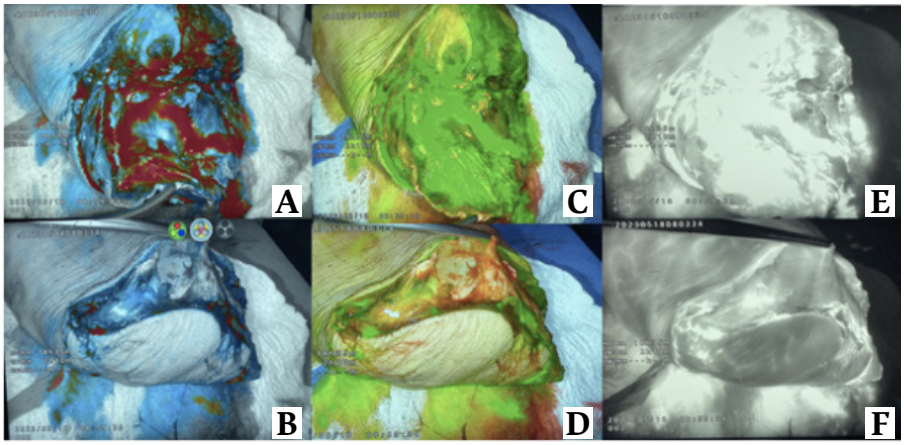

Figure 3. Fluorescence in amputation stump with evidence of blood flow in the muscle and posterior flap. **A and B.** Color fluorescence mode. **C and D.** Overlay mode. **E and F.** Contrast mode.
Source: Images obtained while treating the patient.

After completion of the surgical intervention, and given that her clinical condition was stable, the patient was transferred to the general hospital ward, where her clinical condition showed a favorable evolution in the immediate postoperative period. However, on the second postoperative day, she required the transfusion of two units of packed red blood cells (PRBC) because a low hemoglobin level (8.7 mg/dl) was observed in the follow-up laboratory tests. Moreover, that same day, after being evaluated by the internal medicine service, anticoagulant treatment with enoxaparin was restarted to control her comorbidities. Since there were no complications, she was discharged 2 days after surgery with instructions to attend follow-up appointments with the prosthetics and amputee service to continue with her rehabilitation process.

Five days after surgery, during a follow-up appointment with the prosthetics and amputee service, skin irritation was observed on the stump, so a home nursing visit was requested from the hospital's nursing service. Subsequent follow-ups (four weeks after amputation) showed adequate healing of the stump, with no evidence of complications such as infection or dehiscence (Figure 4). Then, 12 weeks after surgery, she received bilateral prostheses and physical therapy was started in order for her to become adapted to their use (Figure 5).

Figure 4. Appearance of the stump four weeks after surgery. Adequate healing is observed.
Source: Image obtained while treating the patient.

Figure 5. Patient with bilateral prostheses during a physical rehabilitation session.
Source: Image obtained while treating the patient.

Discussion

Approximately 100 000 amputations are performed every year in Colombia in patients with diabetic foot that develop ulcerated lesions. Factors such as age, smoking, and peripheral arterial disease significantly increase the risk of amputation.[8] Besides physical repercussions, the psychological consequences of an amputation can be severe, and for this reason defining the amputation level is essential for improving quality of life, considering that an adequate amputation level facilitates adaptation to prostheses and contributes to the preservation of functional gait.[1]

It has been demonstrated that, from a biomechanical point of view, transtibial amputations are preferable to transfemoral amputations, as the former allow a center of gravity closer to the natural one, facilitating rehabilitation and reducing energy expenditure during walking.[9] This is a relevant factor when defining the level of amputation, since a transfemoral amputation is associated with a higher metabolic demand and worse functional outcomes compared to a transtibial amputation.[9]

Real-time tissue perfusion using ICG angiography has been employed in multiple areas of medicine ever since this stain was approved by the Food and Drug Administration in 1959.[7] This tool allows the surgeon to evaluate in real time and objectively the viability of the tissue,[10] as the staining enables precise visualization of tissue irrigation by binding to plasma proteins.[11,12] In the case of our patient, the CT angiography showed occlusion in the distal third of the left femoral artery (adductor canal area) and in the middle third of the deep femoral artery, so transfemoral amputation was considered the most appropriate procedure. However, with the intraoperative use of ICG angiography to assess skin perfusion in real time, adequate muscle tone, and color in subcutaneous tissues were observed, confirming that perfusion in the soft tissues of the proximal third of the leg was appropriate. Based on this objective assessment, it was decided to perform a transtibial amputation rather than a transfemoral amputation.

Our findings are consistent with studies that have documented the use of ICG angiography as an aid to surgical decision making in amputation. In this regard, it has been reported that this technique not only facilitates the surgical procedure,[6] but also plays a key role in the evaluation of tissue viability in revascularization procedures.[13] Furthermore, recent studies have shown that this tool can be useful in treating patients with diabetic foot disease, as it can be used to assess vascularization and predict ulcer healing.[14]

It is worth mentioning that patients undergoing lower limb amputations face multiple postoperative complications, including surgical site ischemia, hematoma, and surgical wound sepsis.[12] Factors such as the level of amputation, the size of the flap, and the adequate management of the soft tissues have a direct influence on the occurrence of these complications.[15] These complications not only negatively impact patient recovery, but also increase the cost of hospital care. On this matter, a systematic review by Lo *et al.*,[16] reported that the average cost of lower limb amputation due to peripheral vascular disease per patient in 2019 was approximately 14 088 USD, whereas the average cost of amputations secondary to diabetic foot was 17 103 USD. In contrast, the cost of performing intraoperative ICG angiography is significantly lower (approximately $250),[17] making it a potentially cost-effective tool.

Finally, our patient did not present any postoperative complications, which could be explained by the choice of the amputation level using ICG angiography. By making possible an objective intraoperative assessment of tissue perfusion, this tool helped to select an amputation level that favored both better healing and better postoperative functionality. Taking into account the foregoing, the use of this tool could be an effective

strategy for optimizing the management of patients requiring amputations, reducing the risk of complications and reoperations, and improving long-term clinical outcomes.

Conclusion

The intraoperative use of ICG angiography as a complementary tool to define the level of amputation preserved the largest possible amount of viable tissue in our patient, which probably contributed to reducing the risk of postoperative complications, as she experienced no adverse events and did not require reoperation. This, in turn, resulted in a reduction of the costs associated with her treatment.

Although this tool has great potential in surgical decision making during lower extremity amputation, evidence of its usefulness is limited to small sample size studies and other methodological shortcomings.[11,18] Therefore, multicenter studies with larger samples are needed to validate its effectiveness and evaluate its impact on long-term clinical outcomes. In this regard, it should be noted that ICG angiography does not replace conventional techniques to define the amputation level or the clinical criteria traditionally used to determine flap viability but rather serves as a complementary tool to optimize decision making with the potential benefit of reducing the risk of complications.

Informed consent

Both the patient and her legal guardian authorized the use of her clinical data and photographs to prepare this case report by signing an informed consent form.

Conflicts of interest

None stated by the authors.

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