Journal of Neurosurgical Sciences
EDIZIONI MINERVA MEDICA

Application of Indocyanine Green video angiography in vascular neurosurgery

Journal: Journal of Neurosurgical Sciences
Paper code: J Neurosurg Sci-4753
Submission date: May 22, 2019
Article type: Original Article

Files:

1. Manuscript
   Version: 1
   Description: Manuscript
   File format: application/vnd.openxmlformats-officedocument.wordprocessingml.document

Application of Indocyanine Green video angiography in vascular neurosurgery

Enrico Marchese[1], MD, Giuseppe Della Pepa[1], MD, Giuseppe La Rocca[1], MD, Alessio Albanese[1], MD, Tamara Ius[2], G.A. Simboli[1], MD, Giovanni Sabatino[1], MD, PhD

[1]Institute of Neurosurgery, Fondazione Policlinico Universitario A. Gemelli IRCCS, Catholic University, Rome, Italy.

[2] Neurosurgery Unit, Department of Neuroscience, Santa Maria della Misericordia University Hospital, Udine, Italy.

Corresponding:

Giuseppe La Rocca, MD

Fondazione Policlinico Universitario A. Gemelli IRCCS

Neurosurgery Department

Catholic University School of Medicine

Largo Francesco Vito 1 - 00168 Roma, Italy

Email: giuseppe.larocca@policlinicogemelli.it - Tel: +39 06 30154841

Keywords: vascular, aneurysm, indocyanine green, ICG-VA, AVM

Abstract

Indocyanine green video angiography (ICG-VA) is a non-invasive, easy to use and very useful tool for various neurosurgical procedures.

The first application was in neurovascular surgery, because it was born as an intravascular tracer for vessels visualization; this has been really useful in aneurysms, AVMs and dural fistulas surgery where identification, obliteration or patency of vessels is essential.

Introduced in vascular neurosurgery since 2003, ICG-VA applications have broadened over time, both in vascular and in other neurosurgical fields.

As the first, in 2003 Raabe et al. [1] described the use of ICG-VA for intraoperative assessment of cerebral vascular flow, enabling visualization of vessel patency and aneurysm occlusion during aneurysm surgery.

ICG-VA applications in vascular neurosurgery have significantly increased over time including complex aneurysms, bypass, atero-venous malformations (AVM) artero-venous fistulas (AVF), evaluation of cortical perfusion.[2-4].

The procedure can be easily repeated after 5–10min. Adverse reactions are comparable to those of other types of contrast media, with frequencies of 0.05% (hypotension, arrhythmia, or, more rarely, anaphylactic shock) to 0.2% (nausea, pruritus, syncope, or skin eruptions.

The aim of the present study is to systematically analyses ICG-VA applications in vascular neurosurgery, highlighting the reported advantages and disadvantages, and discussing future perspectives.

Overview of Indocyanine Green video angiography in vascular neurosurgery

Aneurysms

The first systematic report on ICG-VA application in cerebral aneurysm surgery was published in 2003 by Raabe et al.[1] Following this preliminary experience, several consistent patient series were published on ICG-VA use in aneurysm surgery by Roessler et al. in 2014[5]. ICG-VA is often compared to micro-doppler and digital subtraction angiography (DSA) to evaluate vascular anatomy, before and after clipping, and to assess correct position of the clip, presence of aneurysm residuals, patency of normal vessels. One interesting paper reports about a patient suffering from a giant aneurysm of the right MCA; indocyanine green was injected inside the aneurysm in order to identify a target middle cerebral artery branch (MCA) for bypass and allowing confident preservation of blood supply to distal areas to the sacrificed vessel.

The study published by Roessler et al. including 295 cases is nowadays the largest published series on this topic[5]. They reported a repositioning of aneurysm clips in 9% of the procedures because of parent vessel or adjacent perforating arteries occlusion not detected by micro-Doppler ultrasonography. Moreover, in 4.5% of the procedures residual perfusion was detected and one or more clips were applied. Nevertheless, postoperative angiography in 9.1% of successful ICG- VA guided clip applications demonstrated unexpected residual aneurysms.

A very interesting study was published by Hardesty et al. [6] where a comparison is between two "eras": the intraoperative DSA one and the ICG-VA. They retrospectively evaluated whether the rates of perioperative stroke, unexpected postoperative aneurysm residual, or parent vessel stenosis differed in 100 patients from each era.

The issue of per-patient cost of intraoperative imaging was also estimated in a study published by Nishiyama et al. [7](patients undergoing ICG-VA and endoscopy in order to facilitate intra- operative real-time assessment of the patency of perforating arteries behind parent arteries or aneurysms). In a more recent paper by Bruneau et al. [8]endoscopic ICG-VA was used in anterior communicating artery aneurysm clipping providing information regarding aneurysm occlusion and patency of parent and branching vessels and small perforating arteries.

During aneurysms surgery, the use of ICG-VA is already consolidated, it's easy, rapid to perform and non invasive[9]; it has good spatial resolution and allows a good evaluation of the complete aneurysm exclusion, neck remnant, blood flow in the parent vessels. A percentage of unexpected neck residuals and close vessels occlusion has been reported (6% in the Dashti et al. study[10]).

Intraoperative ICG-VA is therefore considered a valuable and cost-effective replacement to routine intraoperative diagnostic angiography. Nevertheless, postoperative DSA still cannot be avoided because of a remaining little percentage of inaccuracy of both intraoperative techniques [11]. Thus, care should be taken when considering ICG-VA as the sole means for intraoperative evaluation of aneurysm clip application. Thus, care should be taken when considering ICG-VA as the sole means for intraoperative evaluation of aneurysm clip application.

AVMs

In AVMs surgery, ICG-VA is considered to give a moderate contribution. As reported in the paper by Zaidi et al. [12] it can be useful for the intraoperative mapping of the angio-architecture of superficial AVMs; it gives the possibility to visualize flow variations directly on surgical field and to confirm the occlusion of nidus feeding arteries. Unfortunately, it is considered useless in the residual detection [13], and the difficult visualization in deep located AVMs [14] could limit its application

Indeed in the most important series (56 patients) published by Zaidi et al.[12] do not report any difference between patients undergoing or not ICG-VA in terms of residual disease or clinical outcomes.

Vascular bypasses and low flow malformations

The principal aim of vascular bypass is the preservation of blood flow. Considering the different type of bypass (i.e. STA-MCA OA–PICA, radial artery, saphenous vein, IC–

IC, STA–PCA) we found that the application of ICG-VA is quite mandatory to evaluate the patency of the vessels and thus the blood flow.[15]

Januszewski et al. [16] identified 3 different pattern on ICG-VA angiography to evaluate the patency in the next 24–48 h. Prinz et al. [17]assessed the use of ICG-VA to detect hemodynamic changes within the macro- circulation and microcirculation after bypass. Schuette–Barrow in 2010 [18] together with other collegues [2, 19-21] published ICG-VA application as a tool in a minimally invasive approach for ligation of dural AVFs [22]. Conversely, also in intramedullary cavernomas, ICG can provide useful information about lesion margins and associated venous anomalies [23-26].

In this scenario, we can currently consider the use of ICG-VA of paramount importance also in vascular bypasses and low flow vascular malformations.

Discussion

Intraoperative ICG-VA, nowadays, is a standard visualization tool in vascular neurosurgery.

It was used for the first time as an intravascular tracer for vessels visualization [27]; Thanks to its quickness and non invasiveness and providing real-time information it has become an invaluable tool to intraoperative surgical decision-making;

in addition, recent experiences have shown ICG-VA potential use in a very different set neurosurgical branches, including oncological surgery, endoscopy, pituitary, cerebral hemodynamic studies

During aneurysms surgery it is easy, rapid to perform and non invasive[27] and offers a good spatial resolution[10, 28] and allows a good evaluation of the complete aneurysm exclusion, neck remnant, blood flow in the parent arteries and perforating arteries [27, 28].

By the way, it has a limited view to the operating field [27, 29] and it can give a limited ability to visualize the part of the base behind the aneurysm dome in deeply located aneurysms in case of blood clot or intramural thrombi or calcifications [10, 30].

Intraoperative ICG-VA is considered a valuable cost-effective replacement to routine intraoperative diagnostic angiography but postoperative DSA wouldn't be avoided because of a remaining little percentage of inaccuracy[6].

ICG-VA had also in important role in bypasses surgery because of its definition, direct evidence of graft patency and the identification of the parent and recipient arteries [30-32]. On the other hand, it gives a limited and restricted visualization to the operating field. Januszewski et al. established a classification to evaluate the type of flow through the bypass graft: Type I flow (robust anterograde flow) strongly correlates with early postoperative graft patency, Type II (anterograde flow but delayed compared to other adjacent vascular structures) and Type III (anterograde flow but delayed with no continuity to the bypass site) are both predicative of early graft failure and need to be intraoperative revised in order to avoid postoperative complications.[16]

ICG-VA in the assessment of hemodynamic changes within the macrocirculation and microcirculation after bypass surgery has been detected by Prinz et al. but currently, there isn't a standard intraoperative method to obtain a visualization and quantitative measurement of cortical microcirculatory perfusion. [17]

ICG-VA is also adopted in AVMs surgery: it can be suitable for the intraoperative mapping of the angio-architecture of superficial AVMs giving the chance to visualize flow variations directly on surgical field and to confirm the occlusion of nidus feeding arteries. Beside that it is useless in the residual detection [33] and in deeply deep located AVMs [34]. Basically, there are no difference between patients undergoing or not ICG-VA in terms of residual disease or clinical outcomes as reported by Zaidi et al[12].

Last, but not least, in dAVFs surgery, the main step is the identification of fistulous site. Different studies report 100% correspondence to postoperative controls[19], the identification of the fistulous site and confirmation of its obliteration during surgery [19, 20, 22] and the possibility to identify both the early-filling fistula and the presence of abnormal retrograde drainage thanks to the visualization of the timing and direction of blood flow [20]. On the other hand, the use of ICG-VA, can get and increase of operating time and the limited visualization to the operating field requiring a larger exposition [2, 19].

Future Perspectives

ICG-VA allows evaluation of vessel patency but, unfortunately, does not allow quantitative, time-dependent and spatially precise analysis of intravascular blood flow. In fact, conventional ICG-VA gives information about vessel patency but not quantitative, time-dependent and spatially precise analysis of intravascular blood flow [28].

Faber et al. [35] and Kamp et al.[36] pioneered a color-coded maps of time to half-maximal peak that valuable for giving an overview of blood flow perturbations and distribution by extracting data from conventional ICG-VA[34].

Cortical ICG in the setting of acute SAH can also provides evidence of acute vasoconstriction after haemorrhage and measurement of CBF intraoperatively as stated by Shubert et al. [37].

Lastly, different mini-invasive approached and several high resolution tools are proposed for better intraoperative visualization[38-44]. Nishiyama et al. recently used ICG-VA for endoscopic-assisted aneurysm surgery, to better view perforating arteries, that are often not visible to the sole microscopic view[7].

Conclusions

We can conclude that ICG-VA has reached in recent years a wide utilization in various neurosurgical fields, mainly in vascular neurosurgery surgery. The technique allows future developments such as quantitative evaluation of cerebral blood flow or the combined use with the endoscope. It should be considered among the most promising easy and low cost tools towards the direction of a minimally invasive and safer neurosurgery.

1. Raabe, A., et al., *Near-infrared indocyanine green video angiography: a new method for intraoperative assessment of vascular flow.* Neurosurgery, 2003. **52**(1): p. 132-9; discussion 139.
2. Oh, J.K., et al., *Intraoperative indocyanine green video-angiography: spinal dural arteriovenous fistula.* Spine (Phila Pa 1976), 2011. **36**(24): p. E1578-80.
3. Germans, M.R., et al., *Blood volume measurement with indocyanine green pulse spectrophotometry: dose and site of dye administration.* Acta Neurochir (Wien), 2010. **152**(2): p. 251-5; discussion 255.
4. Cochran, S.T., K. Bomyea, and J.W. Sayre, *Trends in adverse events after IV administration of contrast media.* AJR Am J Roentgenol, 2001. **176**(6): p. 1385-8.
5. Roessler, K., et al., *Essentials in intraoperative indocyanine green videoangiography assessment for intracranial aneurysm surgery: conclusions from 295 consecutively clipped aneurysms and review of the literature.* Neurosurg Focus, 2014. **36**(2): p. E7.
6. Hardesty, D.A., et al., *Safety, efficacy, and cost of intraoperative indocyanine green angiography compared to intraoperative catheter angiography in cerebral aneurysm surgery.* J Clin Neurosci, 2014. **21**(8): p. 1377-82.
7. Nishiyama, Y., et al., *Endoscopic indocyanine green video angiography in aneurysm surgery: an innovative method for intraoperative assessment of blood flow in vasculature hidden from microscopic view.* J Neurosurg, 2012. **117**(2): p. 302-8.
8. Bruneau, M., et al., *Endoscope-integrated ICG technology: first application during intracranial aneurysm surgery.* Neurosurg Rev, 2013. **36**(1): p. 77-84; discussion 84-5.
9. Della Pepa, G.M., et al., *Intraorbital and intracanalicular ophthalmic artery aneurysms. Literature review and report of a case.* Br J Neurosurg, 2014. **28**(6): p. 787-90.
10. Dashti, R., et al., *Microscope-integrated near-infrared indocyanine green videoangiography during surgery of intracranial aneurysms: the Helsinki experience.* Surg Neurol, 2009. **71**(5): p. 543-50; discussion 550.
11. Seifert, V., E. Guresir, and H. Vatter, *Exclusively intradural exposure and clip reconstruction in complex paraclinoid aneurysms.* Acta Neurochir (Wien), 2011. **153**(11): p. 2103-9.
12. Zaidi, H.A., et al., *Indocyanine green angiography in the surgical management of cerebral arteriovenous malformations: lessons learned in 130 consecutive cases.* Neurosurgery, 2014. **10 Suppl 2**: p. 246-51; discussion 251.
13. Ng, Y.P., et al., *Uses and limitations of indocyanine green videoangiography for flow analysis in arteriovenous malformation surgery.* J Clin Neurosci, 2013. **20**(2): p. 224-32.
14. Hanggi, D., N. Etminan, and H.J. Steiger, *The impact of microscope-integrated intraoperative near-infrared indocyanine green videoangiography on surgery of arteriovenous malformations and dural arteriovenous fistulae.* Neurosurgery, 2010. **67**(4): p. 1094-103; discussion 1103-4.
15. Awano, T., et al., *Intraoperative EC-IC bypass blood flow assessment with indocyanine green angiography in moyamoya and non-moyamoya ischemic stroke.* World Neurosurg, 2010. **73**(6): p. 668-74.
16. Januszewski, J., et al., *Flow-based evaluation of cerebral revascularization using near-infrared indocyanine green videoangiography.* Neurosurg Focus, 2014. **36**(2): p. E14.
17. Prinz, V., et al., *FLOW 800 allows visualization of hemodynamic changes after extracranial-to-intracranial bypass surgery but not assessment of quantitative perfusion or flow.* Neurosurgery, 2014. **10 Suppl 2**: p. 231-8; discussion 238-9.
18. Schubert, G.A., et al., *ICG videography facilitates interpretation of vascular supply and anatomical landmarks in intramedullary spinal lesions: two case reports.* Spine (Phila Pa 1976), 2011. **36**(12): p. E811-3.

19. Horie, N., et al., *Intra-arterial indocyanine green angiography in the management of spinal arteriovenous fistulae: technical case reports.* Spine (Phila Pa 1976), 2012. **37**(4): p. E264-7.
20. Hanel, R.A., P. Nakaji, and R.F. Spetzler, *Use of microscope-integrated near-infrared indocyanine green videoangiography in the surgical treatment of spinal dural arteriovenous fistulae.* Neurosurgery, 2010. **66**(5): p. 978-84; discussion 984-5.
21. Simal Julian, J.A., et al., *Indocyanine green videoangiography "in negative": definition and usefulness in spinal dural arteriovenous fistulae.* Eur Spine J, 2013. **22 Suppl 3**: p. S471-7.
22. Fontes, R.B., L.A. Tan, and J.E. O'Toole, *Minimally invasive treatment of spinal dural arteriovenous fistula with the use of intraoperative indocyanine green angiography.* Neurosurg Focus, 2013. **35**(2 Suppl): p. Video 5.
23. Murai, Y., et al., *Indocyanine green videoangiography of optic cavernous angioma - case report.* Neurol Med Chir (Tokyo), 2011. **51**(4): p. 296-8.
24. Endo, T., et al., *Use of microscope-integrated near-infrared indocyanine green videoangiography in the surgical treatment of intramedullary cavernous malformations: report of 8 cases.* J Neurosurg Spine, 2013. **18**(5): p. 443-9.
25. Murakami, K., T. Endo, and T. Tominaga, *An analysis of flow dynamics in cerebral cavernous malformation and orbital cavernous angioma using indocyanine green videoangiography.* Acta Neurochir (Wien), 2012. **154**(7): p. 1169-75.
26. Rodriguez-Hernandez, A. and M.T. Lawton, *Flash fluorescence with indocyanine green videoangiography to identify the recipient artery for bypass with distal middle cerebral artery aneurysms: operative technique.* Neurosurgery, 2012. **70**(2 Suppl Operative): p. 209-20.
27. Fischer, G., A. Stadie, and J.M. Oertel, *Near-infrared indocyanine green videoangiography versus microvascular Doppler sonography in aneurysm surgery.* Acta Neurochir (Wien), 2010. **152**(9): p. 1519-25.
28. de Oliveira, J.G., et al., *Assessment of flow in perforating arteries during intracranial aneurysm surgery using intraoperative near-infrared indocyanine green videoangiography.* Neurosurgery, 2007. **61**(3 Suppl): p. 63-72; discussion 72-3.
29. Xu, B.N., et al., *Microsurgical management of large and giant paraclinoid aneurysms.* World Neurosurg, 2010. **73**(3): p. 137-46; discussion e17, e19.
30. Esposito, G., et al., *Selective-targeted extra-intracranial bypass surgery in complex middle cerebral artery aneurysms: correctly identifying the recipient artery using indocyanine green videoangiography.* Neurosurgery, 2012. **71**(2 Suppl Operative): p. ons274-84; discussion ons284-5.
31. Schuette, A.J., et al., *Indocyanine green videoangiography for confirmation of bypass graft patency.* J Korean Neurosurg Soc, 2011. **50**(1): p. 23-9.
32. Woitzik, J., et al., *Intraoperative control of extracranial-intracranial bypass patency by near-infrared indocyanine green videoangiography.* J Neurosurg, 2005. **102**(4): p. 692-8.
33. Takagi, Y., et al., *Detection of a residual nidus by surgical microscope-integrated intraoperative near-infrared indocyanine green videoangiography in a child with a cerebral arteriovenous malformation.* J Neurosurg, 2007. **107**(5 Suppl): p. 416-8.
34. Takagi, Y., et al., *Evaluation of serial intraoperative surgical microscope-integrated intraoperative near-infrared indocyanine green videoangiography in patients with cerebral arteriovenous malformations.* Neurosurgery, 2012. **70**(1 Suppl Operative): p. 34-42; discussion 42-3.
35. Faber, F., et al., *Enhanced analysis of intracerebral arterioveneous malformations by the intraoperative use of analytical indocyanine green videoangiography: technical note.* Acta Neurochir (Wien), 2011. **153**(11): p. 2181-7.

36. Kamp, M.A., et al., *Microscope-integrated quantitative analysis of intraoperative indocyanine green fluorescence angiography for blood flow assessment: first experience in 30 patients.* Neurosurgery, 2012. **70**(1 Suppl Operative): p. 65-73; discussion 73-4.

37. Schubert, G.A., et al., *Cortical indocyanine green videography for quantification of acute hypoperfusion after subarachnoid hemorrhage: a feasibility study.* Neurosurgery, 2012. **71**(2 Suppl Operative): p. ons260-7; discussion ons267-8.

38. Rigante, M., et al., *Preliminary experience with 4K ultra-high definition endoscope: analysis of pros and cons in skull base surgery.* Acta Otorhinolaryngol Ital, 2017. **37**(3): p. 237-241.

39. Giovanni, S., et al., *Galea-pericranium dural closure: can we safely avoid sealants?* Clin Neurol Neurosurg, 2014. **123**: p. 50-4.

40. Della Pepa, G.M., et al., *Real-time intraoperative contrast-enhanced ultrasound (CEUS) in vascularized spinal tumors: a technical note.* Acta Neurochir (Wien), 2018. **160**(6): p. 1259-1263.

41. Sturiale, C.L., et al., *Minipterional Craniotomy for Treatment of Unruptured Middle Cerebral Artery Aneurysms. A Single-Center Comparative Analysis with Standard Pterional Approach as Regard to Safety and Efficacy of Aneurysm Clipping and the Advantages of Reconstruction.* Acta Neurochir Suppl, 2017. **124**: p. 93-100.

42. La Rocca, G., et al., *Lateral Supraorbital Versus Pterional Approach: Analysis of Surgical, Functional, and Patient-Oriented Outcomes.* World Neurosurg, 2018. **119**: p. e192-e199.

43. Della Pepa, G.M., et al., *Integration of Real-Time Intraoperative Contrast-Enhanced Ultrasound and Color Doppler Ultrasound in the Surgical Treatment of Spinal Cord Dural Arteriovenous Fistulas.* World Neurosurg, 2018. **112**: p. 138-142.

44. Visocchi, M., et al., *10 Levels thoracic no-intrumented laminectomy for huge spontaneous spinal subdural hematoma removal. Report of the first case and literature review.* Int J Surg Case Rep, 2015. **15**: p. 57-62.