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Subjective interpretation of ICG-FA in reconstructive surgery: Perception versus perfusion



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Summary *Background:* Indocyanine green fluorescence angiography (ICG-FA) enables real-time visualization of perfusion in reconstructive surgery. However, interpretation remains largely subjective and may be influenced by multiple factors. This study aimed to evaluate interobserver variability in ICG-FA interpretation and its ability to predict perfusion-related complications.

Methods: Consultants and residents from the Department of Plastic, Reconstructive and Hand Surgery at Amsterdam UMC assessed 30 ICG-FA videos of reconstructive cases, classifying perfusion as normal, suspicious, or compromised. Interobserver agreement was analyzed using Fleiss' Kappa. A generalized linear mixed model (GLMM) was used to evaluate the effect of experience level and the presence of a perfusion-related complication on assessment accuracy. *Results:* Fifteen participants completed the survey (eight residents, seven consultants). Overall agreement was moderate ($\kappa = 0.42$), slightly higher among residents ($\kappa = 0.44$) than consultants ($\kappa = 0.35$). Observers were significantly less likely to correctly assess flap perfusion using ICG-FA in flaps with a perfusion-related complication compared with uncomplicated flaps (OR 0.04, 95% CI 0.003-0.41, $p = 0.007$). Observer experience (resident vs. consultant) did not significantly influence assessment accuracy (OR 1.08, 95% CI 0.52-2.23, $p = 0.83$).

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Conclusion: These findings demonstrate substantial interobserver variability in subjective ICG-FA interpretation and highlight the difficulty of visually identifying venous outflow disturbances and subtle perfusion abnormalities. Quantitative ICG-FA may help address these limitations. © 2026 The Authors. Published by Elsevier Ltd on behalf of British Association of Plastic, Reconstructive and Aesthetic Surgeons. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Indocyanine green fluorescence angiography (ICG-FA) is increasingly used across multiple surgical specialties to support intraoperative assessment of tissue perfusion. In reconstructive surgery, it is commonly applied as an adjunct to clinical evaluation, particularly in mastectomy skin flaps, where it aids in identifying ischemic tissue at risk for necrosis.¹ In this context, quantitative ICG-FA has been introduced to improve reliability and reproducibility, with perfusion thresholds proposed to guide tissue excision.²

However, quantitative approaches have not been standardized in other reconstructive domains leaving surgeons to rely largely on subjective visual interpretation of ICG-FA. In other surgical specialties, subjective interpretation has been associated with substantial interobserver variability, raising concerns about consistency and clinical reliability.³ In reconstructive flap surgery, this variability has not yet been systematically investigated. The aim of this study was to assess interobserver variability in ICG-FA interpretation and to identify aspects of visual assessment that are particularly challenging in reconstructive flap surgery.

To address this aim, a cross-sectional survey study was conducted among consultants and residents from the Department of Plastic, Reconstructive and Hand Surgery at Amsterdam UMC. Participants independently assessed ICG-FA videos obtained from a prospective observational study. All participants provided written informed consent.

Thirty ICG-FA videos representing a broad range of free and locoregional flap reconstructions were selected based on image quality and feasibility. Cases were presented using a standardized layout including clinical context, flap orientation, and area of interest, followed by a fast-forwarded (30-s) ICG-FA video illustrating fluorescence changes over time (Figure 1). Participants classified flap perfusion as normal, suspicious, or compromised based on visual interpretation alone.

Interobserver agreement was evaluated using Fleiss' kappa. Diagnostic reliability was assessed using a generalized linear mixed model (GLMM) with correct versus incorrect assessment as the binary outcome. Correct assessment was defined as scoring uncomplicated flaps as normal and complicated flaps as compromised. Observer role and clinical outcome were

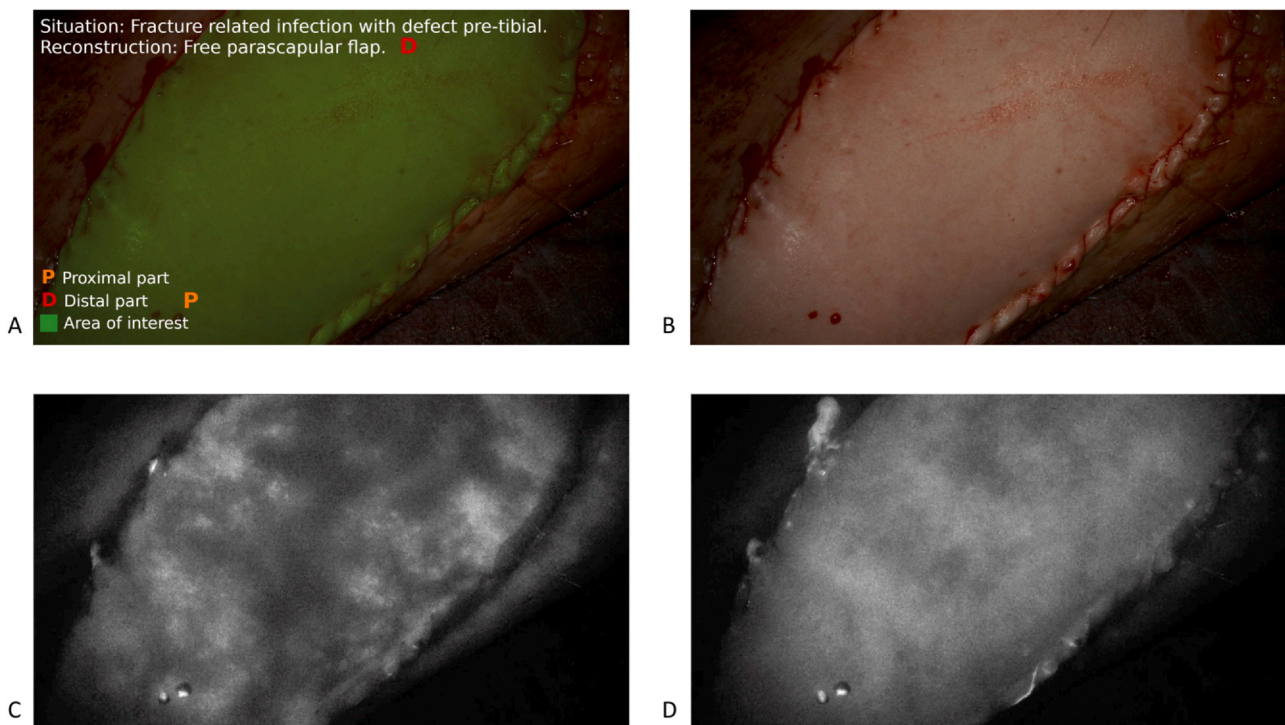


Figure 1 Example of ICG-FA interpretation over time in a free parascapular flap for lower-limb reconstruction. Information panel shown to observers during the survey, including clinical context, orientation (proximal/distal), and area of interest (A). White-light image of the free parascapular flap (B). Early inflow phase with heterogeneous fluorescence (C). Later ICG-FA phase showing apparently uniform fluorescence, which was scored as normal by most observers (D). The flap subsequently developed venous congestion within hours postoperatively. This case illustrates that early heterogeneous fluorescence and subtle outflow abnormalities may be overlooked when perfusion is assessed visually over time.

Table 1 Overview of cases with clinical assessment, outcomes, and observer scores of ICG-FA interpretation.

Case	Flap	Flap type (transfer & vascular pattern)	Patient-related risk factors	Intraoperative clinical assessment	Clinical outcome	Observer scores, n (Normal / Suspicious / Compromised)	Correct ICG-FA interpretation (%)
1	Parascapular	Free - axial	CVD+; Smk form.	Adequate	No complication	15 / 0 / 0	100%
2	Propellor	Pedicled - perforator (PTA)	-	Adequate	Postoperative venous congestion leading to revision surgery	9 / 5 / 1	7%
3	SCIP phalloplasty	Pedicled - perforator	-	Adequate	No complication	13 / 2 / 0	87%
4	YY	Pedicled - random pattern	-	Adequate	No complication	0 / 5 / 10	0%
5	Propellor	Pedicled - perforator (PTA)	-	Adequate	Distal necrosis, leading to partial flap failure	0 / 5 / 10	67%
6	DIEP	Free - perforator	CVD+; Smk form.; Malign.+	Adequate	No	14 / 1 / 0	93%
7	PIA	Pedicled - axial	-	Adequate	Postoperative venous congestion leading to revision surgery	2 / 5 / 8	53%
8	DIEP	Free - perforator	Malign.+; CT+	Adequate	No	15 / 0 / 0	100%
9	ALT	Free - perforator	CVD+; Smk form.; Malign.+; RT+	Inadequate; flap appeared congested	Revision during same procedure; redo venous anastomosis	5 / 9 / 1	7%
10	Parascapular	Free - axial	-	Inadequate; flap appeared pale	Revision during same procedure; redo arterial anastomosis	5 / 9 / 1	7%
11	Parascapular	Free - axial	Smk form.	Adequate	Postoperative venous congestion leading to revision surgery	12 / 3 / 0	0%
12	Ponten	Pedicled - random pattern	CVD+; Smk form.	Adequate	Distal necrosis, leading to partial flap failure	0 / 1 / 14	93%
13	YY	Pedicled - random pattern	Smk form.; Malign.+; CT+; RT+	Adequate	No	15 / 0 / 0	100%
14	Parascapular	Free - axial	-	Adequate	Postoperative venous congestion leading to complete flap failure	10 / 3 / 2	13%
15	Rhomboid	Pedicled - random pattern	-	Adequate	No	7 / 8 / 0	46%
16	DIEP	Free - perforator	Malign.+; CT+	Adequate	No	15 / 0 / 0	100%
17	SCIP phalloplasty	Pedicled - perforator	-	Inadequate; absent distal wound edge bleeding	Revision during same procedure; excision of distal 2 cm (partial flap failure)	0 / 3 / 12	80%
18	Forehead flap	Pedicled - axial	-	Adequate	No	15 / 0 / 0	100%
19	SCIP phalloplasty	Pedicled - perforator	-	Adequate	No	14 / 0 / 1	93%
20	LD + skin island ^a	Free - axial (perforator-based through muscle)	CVD+; Smk form.	Inadequate, flap appeared pale	Revision during same procedure; revision failed (complete flap failure)	0 / 4 / 11	73%
21	TFL + skin island ^a	Free - axial (perforator-based through muscle)	CVD+; Malign.+; RT+	Adequate	No	8 / 5 / 2	53%
22	YY	Pedicled - random pattern	CVD+; DM+	Adequate	No	9 / 6 / 0	60%

ICG-FA, indocyanine green fluorescence angiography; PTA, posterior tibial artery; SCIP, superficial circumflex iliac perforator; DIEP, deep inferior epigastric perforator; PIA, posterior interosseous artery; ALT, anterolateral thigh; LD, latissimus dorsi; TFL, tensor fasciae latae; CVD, cardiovascular disease; DM, diabetes mellitus; Smk curr., current smoker; Smk form., former smoker; Malign., malignancy; RT, radiotherapy; CT, chemotherapy.

^a Musculocutaneous flap: ICG-FA measurements were obtained from the skin island component of the flap.

included as fixed effects, with random intercepts for observer and case.

Fifteen observers completed the assessment (450 observations), including eight residents and seven consultants. Overall interobserver agreement for ICG-FA interpretation was moderate (Fleiss' $\kappa = 0.42$). Agreement among residents was moderate ($\kappa = 0.45$), whereas agreement among consultants was fair ($\kappa = 0.36$).

Outcome analysis was available for the 22 cases in whom the full flap was visible to assess viability. Nine patients (41%) developed a perfusion-related complication. Observers were significantly less likely to correctly interpret ICG-FA in complicated flaps as compared to uncomplicated flaps (OR 0.04, 95% CI 0.003-0.41; $p = 0.007$). Observer experience (resident versus consultant) had no significant effect on assessment accuracy (OR 1.08, 95% CI 0.52-2.23; $p = 0.83$).

Variance analysis demonstrated substantial heterogeneity between cases but minimal variability between observers, indicating that case-specific perfusion patterns were the primary source of interpretive variability. Flaps that later developed venous congestion were frequently misclassified. As illustrated in Figure 1, such cases often showed early heterogeneous fluorescence that appeared visually normal at later time points. Individual case characteristics and observer scores are summarized in Table 1.

The present findings demonstrate substantial interobserver variability in subjective ICG-FA interpretation across a range of reconstructive flap types. Despite increasing clinical use of ICG-FA, observers frequently disagreed in their assessments and often failed to correctly classify flaps that later developed perfusion-related complications.

Interobserver agreement in fasciocutaneous flap assessment was lower than previously reported for gastric conduit perfusion video evaluation.³ Our selected patients represent everyday reconstructive practice but the variability in case load may complicate subjective assessment. Experience and training may be necessary, although our residents had a slightly higher agreement as compared to consultants.

Interpretive variability was greatest in cases that presented with venous congestion. Venous outflow compromise does not produce a clearly defined fluorescence pattern and may involve subtle, time-dependent changes in fluorescence, such as reduced or uneven fluorescence intensity and prolonged dye retention,⁴ whereas ischemia manifests as clearly demarcated areas with absent or markedly reduced fluorescence.⁵

The clinical relevance of these findings is most apparent in free and propeller flaps used for complex reconstructions, such as lower extremity injuries and head and neck reconstruction. In these settings, venous congestion is a frequent cause of early flap compromise, and timely intraoperative recognition is essential to enable appropriate interventions. The features of congestion may be challenging to assess using visual interpretation alone and likely contributed to the high interobserver variability observed in this study, in which venous congestion accounted for the majority of perfusion-related complications.

This study is limited by a relatively small number of observers and cases. Assessments were based on fast-

forwarded ICG-FA videos without full intraoperative context, which may have influenced interpretation.

Subjective interpretation of ICG-FA shows substantial interobserver variability in reconstructive flap surgery and is particularly limited in identifying venous outflow problems. These findings support further evaluation of quantitative ICG-FA methods to improve detection of early perfusion abnormalities associated with flap-related complications.

Ethical approval

This study was approved by the Institutional Review Board (IRB) of Amsterdam UMC (NL2025.0625).

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Declaration of Competing Interest

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.bjps.2026.02.044](https://doi.org/10.1016/j.bjps.2026.02.044).

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