Journal of Pediatric Surgery xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.sciencedirect.com/journal/journal-of-pediatric-surgery

Review Article

Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients

Philipp O. Szavay [a], Alex Bondoc [b], Ciro Esposito [c], Seth D. Goldstein [d], Marc Harms [e], Grzegorz Kowalewski [f], Timothy B. Lautz [d], Manuel Lopez [g], Max Pachl [h, q], Samir Pandya [i], Nelson Piché [j], Steven S. Rothenberg [k], Jetske Ruiterkamp [l], Stefan Scholz [m], Benjamin Zendejas [n], Rebecca M. Rentea [o, p, *]

[a] Department of Pediatric Surgery, Lucerne Children's Hospital, Lucerne, Switzerland
[b] Department of Pediatric General and Thoracic Surgery, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA
[c] Division of Pediatric Surgery, Federico II University Hospital, Naples, Italy
[d] Division of Pediatric Surgery, Department of Surgery, Northwestern University Feinberg School of Medicine, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, USA
[e] Stryker Endoscopy, Stryker Nederland BV, Amsterdam, CM 1101, Netherlands
[f] Department of Pediatric Surgery and Organ Transplantation, Children's Memorial Health Institute, 04-730 Warsaw, Poland
[g] Division of Pediatric Surgery, Val d'Hebron Maternity and Children's Hospital, Barcelona, Spain
[h] Department of Paediatric Surgery and Urology, Birmingham Women's and Children's NHS Foundation Trust, UK
[i] University of Texas Southwestern Medical Center, Dallas, TX 75235, USA
[j] Division of Pediatric Surgery, Centre Hospitalier Universitaire Ste-Justine, Université de Montréal, Montréal, Québec, Canada
[k] Division of Pediatric Surgery, Department of Surgery. Rocky Mountain Hospital for Children, Denver, CO 80205, USA
[l] Division Child Health, Wilhelmina Children's Hospital, University Medical Center Utrecht, Pediatric Surgery, Utrecht, EA 3584, Netherlands
[m] Division of Pediatric General and Thoracic Surgery, UPMC Children's Hospital of Pittsburgh, University of Pittsburgh, Pittsburgh, PA, USA
[n] Department of Surgery, Boston Children's Hospital, Boston, MA, USA
[o] Comprehensive Colorectal Center, Section of Colorectal and Pelvic Reconstructive Surgery, Department of Pediatric Surgery, Children's Mercy-Kansas City, Kansas City, MO, 64108, USA
[p] University of Missouri– Kansas City, Kansas City, MO 64108, USA
[q] Cancer Research UK Clinical Trials Unit, Institute of Cancer and Genomic Sciences, University of Birmingham, UK

ARTICLE INFO

Article history:
Received 19 January 2024
Received in revised form
20 July 2024
Accepted 26 July 2024

Keywords:
Indocyanine green fluorescence
Iindocyanine green laser angiography
Tissue perfusion
Fluorescence angiography
Immuno-fluorescence
Pediatric surgery
Fluorescence-guided surgery
Fluorescence imaging
Near-infrared dyes

ABSTRACT

Background and aims: Indocyanine Green Fluorescence (ICG-F)- guided surgery is becoming an increasingly helpful tool in pediatric surgical care. This consensus statement investigates the utility of ICG-F in various pediatric surgical applications, primarily focusing on its evidence base, safety, indications, use across different surgical specialties and dosing strategies. The aim is to establish an international consensus for ICG-F use in pediatric surgery.
Methods: An international panel of 15 pediatric surgeons from 9 countries was assembled. The structured process consisted of a rapid scoping review, iterative discussion sessions, mixed-methods studies with key stakeholders, and voting rounds on individual statements to create draft consensus statements.
Results: 100 articles were identified during the review and summarized by application. Based on this condensed evidence, consensus statements were generated after 3 iterative rounds of anonymous voting. Key areas of agreement were quality of evidence, the safety of ICG, pediatric surgical indications, utilization per surgical specialty, and dosing of ICG.
Conclusion: This consensus statement aims to guide healthcare professionals in managing ICG-F use in pediatric surgical cases based on the best available evidence, key stakeholder consultation, and expert opinions. Despite ICG-F's promising potential, the need for higher-quality evidence, prospective trials,

* Corresponding author. Children's Mercy Hospital-Kansas City, Pediatric Surgery- Comprehensive Colorectal Center, 2401 Gillham Road, Kansas City, MO, USA. Tel.: +1 816 234 3575.
E-mail address: rrentea@cmh.edu (R.M. Rentea).

https://doi.org/10.1016/j.jpedsurg.2024.07.042

Indocyanine green
Fluorescein sodium

and safety studies is underscored. The consensus also provides a framework for pediatric surgeons to utilize ICG-F effectively.

Level of Evidence: III.

1. Introduction

Indocyanine Green (ICG) is a water-soluble, tricarbocyanine dye initially synthesized in the early 1950s. Its medical utility was recognized soon after its discovery, and it gained approval from the U.S. Food and Drug Administration (FDA) in 1959 for use in clinical settings. Primarily used as a diagnostic agent, ICG has been employed in various medical applications due to its unique physicochemical properties, notably its high binding affinity to plasma proteins and its excitation and emission spectra in the near-infrared (NIR) range [1,2].

ICG has been initially used in cardiology to evaluate cardiac output, liver function, and circulatory parameters. In ophthalmology, ICG angiography has been used for decades to visualize the choroidal blood flow, aiding in diagnosing and managing conditions like age-related macular degeneration and other choroidopathies.

ICG-fluorescence imaging (ICG-F) applications have expanded to various surgical fields, including oncological surgery, neurosurgery, and gastrointestinal surgery. It aids in intraoperative visualization, tissue perfusion assessment, and lymphatic mapping, among other functions. Recent research also explores its use in pediatric populations across different surgical specialties.

The evidence base for ICG-F use in pediatric surgery is primarily built on small-scale, retrospective studies, highlighting the need for high-quality, prospective research to confirm its potential and explore new applications [3]. While ICG-F holds much promise, it remains unclear whether its use improves surgical outcomes in the pediatric population. The application characteristics of pediatric patients, distinct from adults, may influence the practical applications of ICG-F, necessitating age and pathology-specific guidelines for its use.

1.1. The need for consensus

A set of guidelines for using ICG-F in pediatric surgery was proposed, addressing central issues such as the quality of current evidence, safety of ICG, specific pediatric indications, application across surgical specialties, and dosing strategies.

We hypothesize that ICG-F can facilitate surgical procedures, improve decision-making, and decrease complications in pediatric surgery. This consensus statement offers clinicians, researchers, and surgeons an authoritative reference point for using ICG-F in pediatric surgery, formulating research objectives, promoting the development of evidence-based guidelines, and identifying areas requiring further in-depth exploration.

2. Methods

2.1. Phase 1: Literature review

PubMed was systematically searched via a scoping review (intended to map the existing literature on a specific topic quickly) [4–6] for articles on the use of ICG-F in pediatric surgery. Article reference lists were additionally hand-searched. The review aimed to identify, categorize, and summarize relevant publications to provide insights into current practices, clinical outcomes, and gaps in the existing body of evidence. Two researchers (MH and RMR) independently conducted the study selection and screening process. Standardized data extraction forms were used across all topics. A uniform Excel database template for entering the data extracted from the selected papers was provided to all panel participants. The template contained predefined fields. The search methodology is reported in Supplement 1 and the PRISMA flow chart (Fig. 1).

Each article reviewed was assigned a level of evidence using the original Center for Evidence-Based Medicine levels Level of evidence was classified according to Oxford Centre for Evidence-Based Medicine (OCEBM) guidelines (http://www.cebm.net/ocebm-levels-of-evidence/) and provided a grade of recommendation (GoR) [7].

2.2. Phase 2: Stakeholder consultation and development of the consensus process

A mixed-method survey via email (Supplement 2) and interviews involving key stakeholders was undertaken to explore clinical experiences, safety perceptions, and utilization preferences. The Internal Review Board approved the study (IRB- 00002938). All participants provided informed consent. With the findings from these interviews, 15 expert pediatric surgeons, each with over five years of post-qualification experience, were selected via snowball and purposive sampling, informing the content of the drafted consensus statements.

2.3. Phase 3: Delphi voting rounds

A modified electronic Delphi technique [8] was utilized to develop the consensus statements. The draft consensus statements, and evidence narrative syntheses generated from Phases 1 and 2 were presented to the panel electronically. The first round involved presenting the literature review and quality of the evidence to determine preliminary clinical consensus needs and address discrepancies. Panelists reviewed these findings to agree upon or adjust recommendations. The panelists were invited to provide comments, propose additional supportive evidence, and suggest statement modification.

The steering group retrieved the modified statements based on the feedback and distributed the statements via RedCap™ survey, expressing agreement, disagreement, or neutrality. The process was repeated until at least 80% agreement was achieved on each statement. Recommendations surpassing this threshold are reported.

3. Results and consensus recommendations

3.1. Quality of evidence

The initial search identified 558 titles, from which 77 abstracts were screened, 46 were located by additional methods, and 100 full-text papers were reviewed. The included studies are diverse,

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

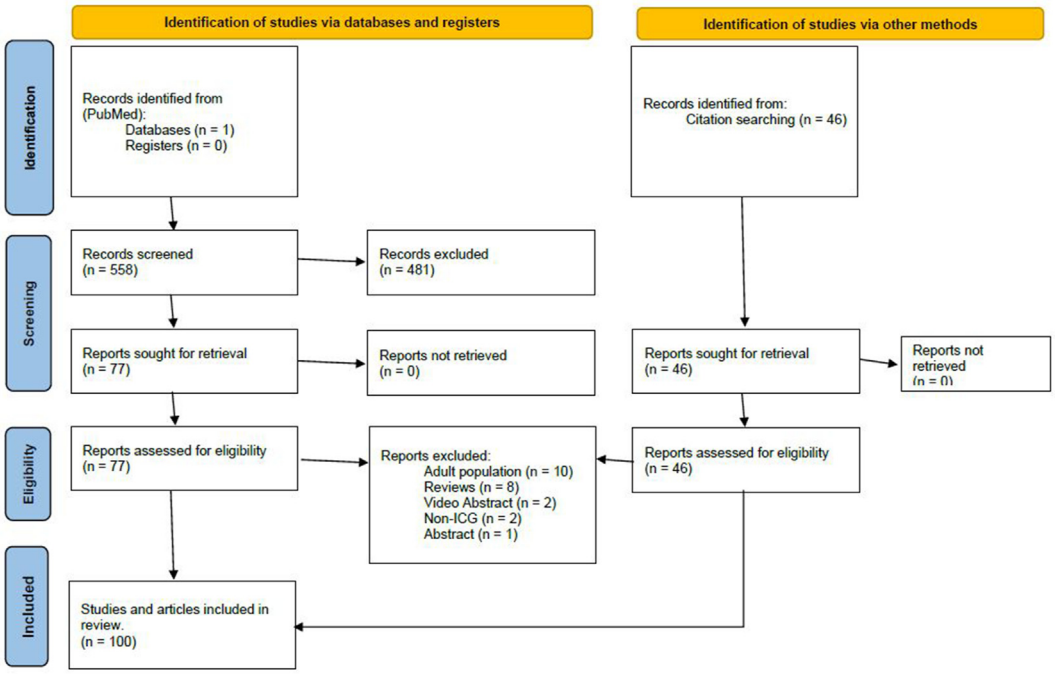

Fig. 1. Preferred reporting items for Systematic Review and Meta-Analyses (PRISMA) methodology. 558 records were identified through database searches, and 123 records remained after duplicates were removed. 100 full-text articles were assessed. Some articles addressed more than one of the pre-identified sections of the paper.

comprising 41 case reports, 18 case series, 21 retrospective studies, 13 prospective studies, and 7 others of various types (Fig. 2).

3.1.1. Recommendation

The panel unanimously agreed on the need for high-quality research and standardized ICG-F results reporting.

3.2. Safety of ICG

ICG has been utilized as a medical dye since the 1950s, with a favorable safety profile. A A study of high doses of 75mg/patient and a concentration of 25 mg/mL study on elderly ophthalmologic patients in early 1990 demonstrated severe 0.05%–0.07%, moderate 0.2%, and mild allergic reactions occurring in 0.15% of exposed patients [9]. In the pediatric population, in a combined study of 75 (45

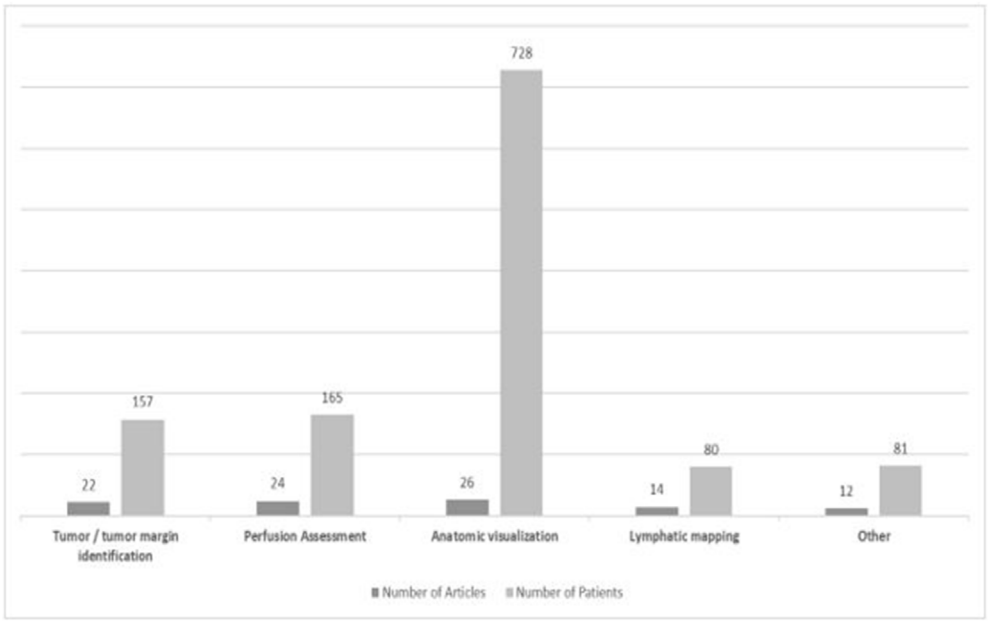

Fig. 2. Common Use of Indocyanine Green Fluorescence in Pediatric Patients. Numbers represent the number of articles identified for each application (dark grey) and several reported cases per application (light grey). Several articles in this rapid scoping review reported multiple applications per case. The number of cases per application is an estimation because many authors report multiple applications per case.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

receiving ICG-F) patients evaluating gastrointestinal perfusion, no complications were noted [10]. A recent Pediatric Health Information System (PHIS) database study of ICG-F in pediatrics between 2016 and 2021 in 1270 cases across 38 participating hospitals demonstrated no adverse events [11]. Of the 100 articles reviewed, 44 did not provide any safety information, and 56 articles reported no ICG-related complications except two cases of temporary skin color change from dermal ICG administration [12,13].

3.2.1. Statements and observations

1. Safety profile: ICG-F utilization has demonstrated a favorable safety profile, including very young/small patients with rare allergic reactions.
2. Pediatric safety: while ICG-F utilization has increased, data on pediatric safety reporting remains limited.
3. Reported adverse events: when present, manifest as transient phenomena (skin discoloration and dye retention without necessitating medical intervention).
4. Data reporting: future research and study reporting should commit to continued attention to possible unintended side effects to provide a more complete understanding of ICG's risk profile in pediatric applications.

3.2.2. Recommendation

- We recommend utilization of ICG-F utilizing previously published weight-based dosing given the positive safety record.
- This recommendation received a 100% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.3. Indocyanine green fluorescence in pediatric Surgical applications

ICG-F continues to have an expanded role in pediatric surgery, enhancing real-time visualization across applications such as tumor visualization, perfusion assessment, visual assessment of anatomical structures, and lymphatic mapping, among other clinical utilities. Supplement 3 offers an overview of the articles by surgical discipline.

3.4. Tumor visualization and tumor margin identification

In tumor visualization and margin identification, 22 articles highlighted the efficacy of ICG-F for both primary and metastatic tumors [14–35] (Table 1). Because ICG is hepatically cleared, ICG-F has proven most helpful for hepatic tumors, both for local control and metastatic operations. The utility of ICG-F for other tumor types, including bone tumors, soft tissue sarcomas, and Wilms tumors, has been more variable and remains under investigation. For oncologic procedures, ICG-F surgery generally relies on administering a larger dose of ICG administered 24 or more hours in advance with washout of the dye from normal tissue but retention in the abnormal tumor tissue (“enhanced permeability and retention effect”). However, false positives remain challenging due to inexperience with the technology, background fluorescence, and lack of objective criteria for assessing fluorescent signals (REF Yamada). The timing varies based on the malignancy type and administration route. The rarity of pediatric solid tumors limits the scope and power of trials to evaluate ICG fluorescent guidance's efficacy, and its impact on morbidity, survival, and quality of life remains unknown. Harris (2023) [21] explored using ICG in minimally invasive surgery for pediatric oncology patients. The results indicate that ICG can be used safely and effectively to identify tumor margins and lymph node sampling during MIS for oncological disease (Please see Thoracic Section applications of pulmonary metastasectomy and lung biopsy).

3.4.1. Hepatoblastoma

Intraoperative IV ICG administration shows rapid liver uptake with initial tumor sparing, but background liver fluorescence may persist up to 24 h. Administration at least 48 h before resection is advised to minimize bowel fluorescence interference. The utility of ICG fluorescence in identifying deeper hepatic lesions is limited by near-infrared light tissue penetration of 5–10 mm [36]. Qui et al. (2022) [37] used intravenous ICG at 0.5 mg/kg 48 h before surgery, adjusting resection planes according to liver fluorescence, resulting in no recurrences to a median follow-up of 24 months. Shen's study (2023) [26], performed a retrospective analysis of 23 children who underwent hepatoblastoma resection using IV ICG (0.5 mg/kg, 48–72 h preoperatively) to visualize hepatoblastoma lesions, achieving negative resection margins in all cases.

3.4.2. Nephroblastoma

Nephroblastoma, the most common renal malignancy in children, presents with bilateral tumors in 5% of cases, necessitating nephron-sparing surgery. Abdelhafeez et al. [15] used IV ICG for nephron-sparing surgery in eight children (12 kidneys) with nephroblastoma, demonstrating renal parenchymal uptake and tumor tissue sparing. This pattern contrasts with “second window” observations in other tumors but matches adult renal tumors. Equivalent positive margin rates with ICG fluorescence compared to unguided resections were demonstrated, but it remains unclear to what extent ICG fluorescence helps achieve negative margins in nephron-sparing nephrectomies.

3.4.3. Statements and observations

1. Efficacy in Tumor Visualization ICG-F can significantly enhance the visualization of hepatic tumors, especially in metastatic settings, and play a pivotal role in delineating tumor margins.
2. Application in Various Tumors: The effectiveness of ICG-F for bone tumors, soft tissue sarcomas, and Wilms tumor remains under evaluation.
3. Procedure Specificity: For visualization during primary hepatic tumors (Hepatoblastoma, hepatocellular carcinoma) or pulmonary metastasis procedures, ICG 24 h or more before the surgery, leveraging the “enhanced permeability and retention effect,” is recommended. However, ICG at the induction of anesthesia or during the procedure is essential in assessing differences in perfusion (for example, pheochromocytoma and insulinoma).
4. Safety and Efficacy in Pediatric Oncology: ICG-F application is both safe and effective in minimally invasive surgeries for pediatric oncology patients with known oncology subtypes that fluoresce.
5. Utility in Hepatoblastoma: Studies underscore the value of ICG-F in surgical margin identification and risk reduction of residual tumors during hepatoblastoma resections in pediatric populations.
6. Recommendation for Future Applications: Ongoing research and clinical trials are encouraged to explore the broader applicability, refine guidelines, refine reporting to correlate with tumor reporting guidelines, and further ascertain the safety and efficacy of ICG-F across diverse pediatric oncologic conditions.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

Table 1
Tumor visualization utilizing Indocyanine Green Fluorescence (ICG-F).

Citation	Sample Size	Age, Mean (Range)	Procedure	ICG Dosing [mg/kg body weight]	Injection Protocol	Adverse Events
General						
Abdelhafeez, 2023	12	10.5 Y	Tumor resection	1.5 mg/kg	Intra-op	No ICG-related adverse events.
Delgado-Miguel, 2023	1	8 M	Tumor resection	0.5 mg/kg	24 h before surgery	No ICG-related adverse events.
Harris, 2023	14	8–185 M	Tumor resection or metastasectomy	0.5–2.0 mg/kg	Pre-operatively, IV (ICG during induction of anesthesia)	No ICG-related adverse events.
Richard, 2023	5	2.1–17.9 Y	Tumor resection	1.5 mg/kg	24h pre-operatively	No ICG-related adverse events.
Shen, 2023	23	(5 D to 80 M), Median 26 M	Surgical resection (open)	0.1 mg/kg	IV, 24–48 h before surgery	N.R.
Shirota, 2017	1	15 Y	Abdominal wall resection	0.05 mL (0.125 mg) - 3 injections	Sub-Q and intradermally into tumor core and margin, 20 h before	N.R.
Sound, 2016	1	16 Y (adult: 28–71 Y)	Robotic adrenalectomy	Per injection: 2.5–6.3 mg; Per patient: 7.5–18.8 mg; 15 mg/10 mL solution; 2–3 injections	IV, intraoperatively	No ICG related adverse events.
Tsuzuki, 2014	3	13 - 14 Y	Neuroendoscopic biopsy, tumor biopsy endoscopically, etc	12.5 mg	Bolus injection, intraoperatively	No ICG-related adverse events.
Liver						
Chung, 2020	1	9 Y	Laparoscopic hepatectomy	0.5 mg/kg	24h pre-operatively	No ICG-related adverse events.
Mitani, 2014	1	32 months	ICG-NIR for the intraoperative identification of small HB for tumor resection	0.5 mg/kg	Pre-operatively (2 days) injected intravenously	No ICG-related adverse events.
Souzaki, 2019	5	12 - 36 Y	Extended hepatectomy and Liver transplants, Lung resections and lobectomies	0.5 mg/kg	IV, 90.5 ± 33.7 h before	No ICG-related adverse events.
Takahashi, 2019	1	14 Y	Laparotomy for metastasectomy of the peritoneally disseminated HBs	0.5 mg/kg (both procedures)	IV, 72 h before (both procedures)	N.R.
Yamada, 2019	36	8 M–14 Y	13 laparotomies (liver resection), 17 thoracotomies (pulmonary metastases), 6 other (lymph-node metastasis)	0.5 mg/kg	N.R.	N.R.
Yamamichi, 2015	3	1, 2, 6 Y	Hepatectomy, Lobectomy	0.5 mg/kg	IV, 3–4 days before surgery	N.R.
Lung						
Chen-Yoshikawa, 2017	1	3 Y	Resection of lung metastatic lesion	0.5 mg/kg	24h pre-operatively	N.R.
Fung, 2020	1	4 Y	Pulmonary wedge resection	0.5 ml ICG	Injection around the lesion	No ICG-related adverse events.
Kitagawa, 2015	10	1-10 Y	Lung metastasectomies	0.5 mg/kg	Pre-operatively (24 h prior); Intravenous injection	No ICG related adverse events.
Komatsu, 2022	1	1 Y	Lung metastasectomies	0.5 mg/kg	1d Pre-op	N.R.
Whitlock, 2022	14	10–228 M	Thoracoscopic/thoracotomy pulmonary metastasectomy, partial hepatectomy	0.2–0.75 mg/kg	IV, 48–96 h before surgery	No ICG-related adverse events.
Yoshida, 2022	16	4 M–11 Y	Resection of pulmonary metastases	N.R.	N.R.	N.R.
Renal						
Abdelhafeez, 2022	8	(1–10 Y), 3 Y	Nephron-sparing surgery	1.5 mg/kg	IV, day before surgery	No ICG related adverse events.
Bone						
Asayama, 2017	2	11 Y and 7 Y	Skull bone tumor resection	0.2 mg/kg	IV peripheral vein, intraoperatively	No ICG related adverse events.

NR = not recorded, IV = intravenous, Y = year, ICG = indocyanine green.

3.4.4. Recommendation

- ICG-F is an encouraging, emerging tumor visualization and margin identification technology in pediatric oncological surgery. ICG-F significantly improves tumor visualization in hepatic and hepatoblastoma settings. Its efficacy for visualization of other tumors is more variable and remains under investigation. A more robust evidence base achieved through rigorous scientific research is needed to confirm these preliminary findings and to guide its integration into clinical practice protocols. ICG administration timing is based on the difference in the assessment goal desired (perfusion vs. retention).
- This recommendation received a 100 % agreement was reached during the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.5. Perfusion assessment

In 31 articles, ICG-F effectively assessed tissue for bowel, esophagus, abdominal wall, skin flap etc. perfusion [38–66]. Through monitoring ICG-F, surgeons identified compromised perfusion, enabling timely interventions to reduce ischemic risks. Le-Nguyen et al. (2023) [54] conducted a prospective study of 28 pediatric intestinal resections using ICG-F, including 14 patients from the NICU. They found that ICG-F may impact bowel resection sites by improving perfusion assessment and demonstrated a very favorable safety profile, even for very small patients.

3.5.1. Statements and observations

1. ICG-FA is a potential intraoperative tool for real-time tissue perfusion assessment,
2. Current non-randomized data supports ICG-FA's safety and efficacy in pediatric surgeries. Still, robust randomized trials are essential to determine if this impacts complications such as rates of anastomotic leak or stricture.
3. Future research should gauge its broad applicability, effect on outcomes, and potential to reduce ischemic complications.
4. Economic aspects, including cost-effectiveness, should be factored into broader adoption discussions.

3.5.2. Recommendation

- While ICG-FA is a promising pediatric surgical perfusion assessment tool, additional standardization and research are needed to determine its efficacy for avoiding ischemic complications before broader, standardized adoption.
- This recommendation received a 100% agreement was reached during the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.6. Visualization Enhancement

ICG-F enhances intra-operative visualization, aiding surgeons in identifying key structures such as anatomic structures, vessels, and tumors (Table 2). Of 28 identified articles [13,67–89], seven were prospective clinical studies. Esposito et al. compared laparoscopic partial nephrectomy with and without ICG-F in 40 patients, finding that clearer vessels and renal visualization reduced operative time [71]. Esposito et al. (2020) [90] confirmed ICG-F imaging effectiveness and safety in pediatric minimally invasive surgery for abdominal lymphoma and ovarian tumors. A review by Esposito et al. (2022) showed that ICG-F enhances surgical visualization in urologic oncology procedures, particularly through tumor inverse pattern of ICG-F visualization (hypo visualization of tumors) [91].

3.6.1. Statements and observations

1. ICG-F enhances visualization in pediatric surgery via contrasting tissues, enhancing the visibility of vessels, anatomic structures, and tumors.
2. While current studies confirm ICG-F's safety, feasibility, and applicability, large-scale comparative trials are required to validate its use comprehensively.
3. Preliminary findings suggest ICG-F's may reduce operative time and complications related to anatomic visualization.
4. The absence of quantifiable data on ICG-F visualization intensity calls for additional technology capabilities.
5. To achieve the best results, ICG-F integration in surgical procedures should consider the clinical impact, cost-effectiveness, long-term results, and previous publications regarding specific usage conditions.

3.6.2. Recommendation

- We recommend that ICG-F emerge as an asset for intricate visualization in pediatric surgeries. This underlines the importance of thorough research and the establishment of detailed clinical guidelines.
- This recommendation received a 100% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.7. Lymphatic System and Lymphatic mapping

Lymphatic mapping is essential for staging and surgical management in certain pediatric malignancies but carries morbidity. 16 articles described lymphatic drainage pathway mapping facilitated by ICG-F, aiding in the identification and excision of sentinel lymph nodes [12,27,50–52,67,92–101]. ICG-F reduced unnecessary lymphadenectomies and related complications. Jeremiasse et al. (2023) [95] reported ICG-F's feasibility for imaging the sentinel lymph node during pediatric melanoma, squamous cell carcinoma, or sarcoma cases, noting superior detection rate and accuracy. Kato et al. (2019) [96], studied lymphatic malformations and found ICG-F useful in identifying and guiding the treatment of lymph flow patterns in refractory lymphatic malformations. Mansfield et al. (2020) [97] compared the outcomes of retroperitoneal lymph node dissection (RPLND) for para testicular rhabdomyosarcoma, concluding that a retroperitoneoscopic approach, combined with ICG-F, enhanced outcomes.

3.7.1. Statements and observations

1. ICG-F-assisted lymphatic mapping is a promising tool for enhancing the surgical approach to pediatric malignancies.
2. Existing literature affirms the safety and effectiveness of ICG-F for sentinel lymph node detection, but comparative prospective trials are required to ascertain ICG-F's advantage over conventional techniques.
3. Implementing ICG-F for lymphatic mapping may diminish complication risks by obviating certain lymphadenectomy s and enabling precise lymph node operations.
4. ICG-F may be applicable for congenital lymphatic malformation resection cases.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

Table 2
Anatomic visualization utilizing Indocyanine Green Fluorescence (ICG-F).

Citation	Sample size	Age, mean (range)	Procedure	ICG dosing	Injection protocol	Adverse Events
Laparoscopic cholecystectomy						
Bryant, 2020	1	17 Y	Laparoscopic cholecystectomy	N.R.	N.R.	N.R.
Calabro, 2020	51	6 - 18 Y	Laparoscopic cholecystectomy	1 ml 0.25% ICG solution, IV	Intraoperatively	No ICG-related adverse events.
Esposito, 2019	215	Mean: 10.2 Y, (5–17 Y)	Laparoscopic cholecystectomy	0.4 mg/kg	IV, 18h pre-operatively	No ICG-related adverse events.
Esposito, 2021	13	12.9 Y	Laparoscopic cholecystectomy	0.35 mg/kg	15.6h pre-operatively, IV	No ICG-related adverse events.
Esposito, 2022	22	11.5 (7–17) Y	Laparoscopic cholecystectomy	0.35 mg/kg	15.5h pre-operatively, IV	No ICG-related adverse events.
Graves, 2017	11	Mean: 16 Y	Laparoscopic cholecystectomy	Nine milliliters	Direct Gallbladder ICG Injection	No ICG-related adverse events.
Yanagi, 2019	10	74.8 (48–122) D	Near-infrared fluorescence cholangiography	0.5 mg/kg	IV, day before surgery	N.R.
Varicocele Repairs and Renal Procedures						
Esposito, 2019	46	15.8 Y (1–17) Y	Varicocele repairs, nephrectomies, partial nephrectomies, lymphoma excision	0.4 mg/kg	18h pre-operatively, IV	No ICG related adverse events.
Esposito, 2020	76	N.R.	Varicocelectomy, nephrectomies, renal cyst deroofing, thoracoscopic procedures	various	15–18h pre-operatively, intraoperatively	No ICG related adverse events.
Esposito, 2020	46	(1–19) Y	Varicocele repairs, partial nephrectomy, nephrectomy, renal cyst deroofing	0.3 mg/kg	Intraoperatively, IV	No ICG related adverse events.
Esposito, 2021	12	3.9 (1–10) Y	Laparoscopic partial nephrectomy	various, multiple injections (~0.3 mg/kg)	1: inject. ureteral catheter, 2: IV, 3: IV	No ICG related adverse events.
Tomita, 2017	2	13 Y (adult: 20–40 Y)	Laparoscopic varicocelectomy	1 ml of 2.5 mg/ml	IV, intraoperatively	No ICG related adverse events.
Liver and Splenic Procedures						
Bada-Bosch, 2020	1	13 Y	Laparoscopic partial splenectomy	0.2 mg/kg	IV, intraoperatively	N.R.
Kobayashi, 2017	105	Median: 68 Y (17–83 Y)	Liver resection: Portal vein territory identification (PV)	0.25 mg	Intraoperatively, US-guided transhepatic PV injection	No ICG-related adverse events.
Masuya, 2022	1	9 Y	Laparoscopic surgery for congenital biliary dilatation	0.6 mg/kg	Intraoperatively (immediately before CBD dissection), IV	N.R.
Troisi, 2014	1	2 Y	Left lateral sectionectomy for living donor liver transplantation (open approach)	0.1 mg/kg	IV, intraoperatively	No ICG-related adverse events.
Cardiac Procedures						
Kogon, 2009	40	N.R.	Surgical reconstructions for congenital heart defects	1.25 mg in infants (<1 yr), 2.5 mg in children (<16 years), and 5 mg in adults	Intraoperatively, IV	No ICG related adverse events.
Pourmoghadam, 2014	3	7, 14, 15 Y	Congenital cardiac surgery	N.R.	N.R.	N.R.
Other Procedures						
DeLong, 2018	60	(17–87 Y)	Surgical resection	3 mL of ICG (2.5 mg/ml), IV	Intraoperatively	No ICG related adverse events.
Esposito, 2020	3	Mean: 8 Y, (5–15 Y)	Cyst deroofing	0.35 mg/kg	Intraoperatively, IV	No ICG related adverse events.
Lemoine, 2022	1	5 Y	Anastomosis	0.5 mg/kg	IV, intra-op	No ICG related adverse events.
Masuya, 2022	1	13 Y	Laparoscopic dome resection	0.6 mg/kg	Intraoperatively, IV	No ICG related adverse events.
Mayorga-Buiza, 2019	1	Newborn	Reconstruction of the myelomeningocele	1.5 mg/kg	IV, intra	N.R.
Pandey, 2012	6	N.R.	Superficial temporal artery middle cerebral artery anastomosis	0.3 mg/kg	Intraoperatively, IV	No ICG related adverse events.
Shirotsuki, 2018	10	(1–10 D), Mean: 2.0 D	Thoracoscopic tracheoesophageal fistula surgery and thoracoscopic repair of chylothorax	0.025 mg	Inter-toe, 1 h before	No ICG related adverse events.
Tanabe, 2017	8	4 - 13 Y (adult: 23–66 Y)	Fronto-temporal craniotomy	5 mg	IV	N.R.
Ueba, 2020	1	19 M	Resection of spinal cord hemangioblastoma	0.2–0.5 mg/kg (5.0 mg)	IV, intraoperatively	N.R.

5. Further work is required to determine whether ICG-F can prevent the need for preoperative Tc lymphoscintigraphy.

3.7.2. Recommendation

- ICG-F is a pivotal advancement in pediatric lymphatic mapping. It showcases the potential for refining surgical accuracy and decreasing associated risks. Embracing ICG-F in this domain requires comparative effectiveness studies.
- This recommendation received a 100% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.8. Fluorescence cholangiography

In total, 23 articles describing the application of ICG-F in hepatopancreatobiliary surgery [18,24,26,29,30,32–34,40,44,53,68,69,75–78,80,81,87,89] covering procedures such as laparoscopic cholecystectomy, Kasai procedure, and partial hepatectomy. Calabro et al. (2020) [69] studied the effects of ICG-F cholangiography (ICG-FC) during laparoscopic cholecystectomy in 50 pediatric patients, finding it safe and effective for biliary tree identification. Esposito et al. published two retrospective studies in 2019 and 2022 [73,75]. The first analyzed 215 children's long-term outcomes after laparoscopic cholecystectomy, showing its long-term safety and effectiveness. The 2022 study on 43 patients compared standard laparoscopic cholecystectomy to ICG-FC cholecystectomy. ICG-FC enhanced visualization and reduced specific operative step time, but overall operative time and hospital stay were insignificant between the comparative groups.

3.8.1. Statements and observations

1. ICG-F is a safe and potentially effective instrument for a range of hepatobiliary operations within the pediatric population.
2. Existing research validates ICG-F's capability to improve visual clarity during surgery, especially in laparoscopic cholecystectomy, despite unclear impact on operative time and reduction of complications.
3. Emphasis should be placed on future research and standardizing application guidelines across pediatric hepatobiliary surgery.

3.8.2. Recommendation

- While current evidence supports the implementation of ICG-F in pediatric HPB surgery for enhanced surgical outcomes, further rigorous research is needed to substantiate these findings and incorporate them into clinical guidelines.
- This recommendation received a 93% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.9. Pediatric colorectal and pelvic reconstructive surgery

ICG-F is increasingly utilized in pediatric colorectal and pelvic reconstruction surgeries [49,57,62,66], aiding in repairs like anorectal malformations, Hirschsprung disease, and complex reoperations. It proves useful for evaluating tissue perfusion in structures such as the neovagina and colon and is crucial in re-operative fields for assessing pedicle viability. In Hirschsprung disease, ICG-F assesses visualizing colonic derotation and selecting vessels for division [60]. Clinical findings in adult colorectal surgeries demonstrate that ICG-F enhances surgical quality and reduces complications [102]. While one must be cautious extrapolating findings to pediatrics, ICG-F was demonstrated as safe and feasible in intestinal resections, with positive feedback from the surgical team, suggesting improved visualization and patient outcomes [54].

3.9.1. Statements and observations

1. ICG-F has demonstrable efficacy in enhancing surgical visualization and decision-making in pediatric colorectal and pelvic reconstructive surgeries for viability of bowel pedicles and anastomotic perfusion.
2. Extrapolation from adult data suggests similar benefits in pediatric settings, albeit this requires more rigorous validation.

3.9.2. Recommendation

- We recommend the role of ICG-F as a safe and effective tool in pediatric colorectal and pelvic reconstructive surgeries, albeit more robust research is necessary for full clinical validation.
- This recommendation received a 100% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.10. Pediatric urological Surgeries and the role of ICG-F

Ten studies examined the utility of ICG-F in pediatric urological procedures [15,38,59,71,72,75,86,103,104]. ICG-F was employed in lymphatic sparring varicocele repairs, various renal surgeries (partial and total nephrectomies and renal cyst unroofing), ureteral mapping, and evaluating vascular and tissue perfusion for living-donor kidney transplantation. It has also been utilized in complex duplex renal surgeries, retroperitoneal lymph node dissections, and to define the ureter during tumor resections (ICG-F applied cystoscopically). Esposito et al. (2020) [72] detailed 57 urological procedures, including 41 varicocele repairs featuring intraoperative lymphography and 16 renal surgeries. Intravenous injection of ICG was used for renal procedures, whereas intra-testicular injection was employed for varicocele repairs, resulting in visualization within 30–60 s after injection. The study confirmed ICG as a reliable tool for improving visualization in pediatric urology.

3.10.1. Statements and observations

1. ICG-F is a safe and effective tool for visualizing anatomical and vascular structures in pediatric urological surgeries.
2. It proves essential for renal surgeries, ureteral mapping, and varicocele repairs with lymphography.
3. Intravenous or intra-testicular ICG administration results in rapid visualization, enhancing surgery outcomes.
4. Further research and standardized training for ICG-F applications are encouraged.

3.10.2. Recommendation

- ICG-F provides a reliable and safe means to visualize anatomical and vascular structures in pediatric urological procedures. It is crucial for renal operations, ureteral mapping, and lymphographic varicocele repairs. Rapid visualization is achievable through intravenous or intra-testicular ICG administration, optimizing surgical results. Continued research and uniform training for its application remains paramount.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

- This recommendation received a 87% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.11. Pediatric neurosurgical applications of ICG-F

Ten studies examined ICG-F's role in pediatric neurosurgical procedures [16,31,47,48,61,63,83,85,88]. ICG-F enhances the visualization and localization of cerebral lesions and maps vascular structures during operations, including tumor resections and arteriovenous malformation surgeries. Lehner et al. (2023) [105] demonstrated ICG-F's ability to visualize the basilar artery during an endoscopic third ventriculostomy for an infant with congenital hydrocephalus. Horie et al. (2014) [48] evaluate the utility of ICG video angiography (ICG-VA) in 50 patients to assess postoperative hyperperfusion in Moya and atherosclerotic disease cases. They found that ICG-VA provides real-time cerebral blood flow data and helps identify patients at risk for postoperative hyperperfusion. Tanabe et al. (2017) [85] studied 19 patients (8 pediatric) and demonstrated ICG-F's efficacy in visualizing the middle meningeal artery before craniotomy for Moya disease.

3.11.1. Statements and observations

1. ICG-F is an instrumental tool in pediatric neurosurgical applications, playing a significant role in enhancing visualization, delineating cerebral and vascular structures, and tissue perfusion.
2. The technology demonstrates utility in intraoperative applications, contributing significantly to the safety and efficacy of complex procedures.
3. Evidence from prospective studies suggests that ICG-F can provide real-time information crucial for surgical 44 decision-making in intricate vascular neurosurgical diseases like MMD.

3.11.2. Recommendation

- We recommend ICG-F, which has emerged as a useful tool in pediatric neurosurgery, showing promise in various applications ranging from lesion visualization to intraoperative guidance. However, further research is warranted to validate its clinical utility across broader neurosurgical contexts.
- This recommendation received a 80 % agreement in the first round of the online survey.

Level of evidence 4, Grade of Recommendation D.

3.12. Thoracic

Sixteen articles in the review discussed the utility of ICG-F in pediatric thoracic surgery [13,15,17,19–23,29,32–35,84,105,106] covering thoracoscopic tracheoesophageal fistula surgery, tumor resections, lung metastasectomies, and congenital cardiac surgery, thoracoscopic vascular ring surgery, and thoracoscopic repair of chylothorax. A prospective study by Abdelhafeez et al. (2023) [14] investigated ICG-F's efficacy in localizing metastatic pulmonary nodules in pediatric patients with solid tumors. Of the 50 patients with 63 pulmonary nodules, ICG-F accurately detected 75% of positive nodules, falling short of the 90% accuracy goal. Notably, while pre-operative CT missed 26% of nodules linked to primary liver tumors, ICG-F was sensitive to them. The study advocated for further ICG-focused trials and measured the use of ICG-F based on tumor histology. The study also suggested the cautious application of ICG-F imaging in patients with non-hepatic tumor metastases, depending on the tumor histology.

Intraoperative ICG fluorescence has been used to identify hepatoblastoma tissue in the lungs. Lung tissue does not absorb ICG dye, enhancing contrast with metastatic lesions. Kitagawa (2015) [22] used IV ICG at 0.5 mg/kg 24 h prior to thoracotomy, removing 250 fluorescently labeled lesions across 37 operations with five non-fluorescent nodules resected that were not malignant and ICG imaging on chemotherapy-resistant hepatoblastoma pulmonary metastases in n = 10 patients. The results show that this method can be highly effective in detecting small lesions and can be a valuable tool for surgeons. Whitlock et al. [32] reported a sensitivity of 77% for pulmonary disease, with ten fluorescent-negative malignant lesions. These findings suggest that ICG fluorescence-guided surgery for pulmonary metastases may improve metastasectomy completeness, though certain tumor subtypes may show limited ICG retention.

3.12.1. Statements and observations

1. ICG-F has demonstrated utility in many pediatric thoracic surgical interventions.
2. ICG-F has a 75% accuracy for metastatic pulmonary nodules, without meeting the predefined target accuracy rate of 90%, but picks up 26% of preoperative CT missed nodules from hepatic solid tumors.

3.12.2. Recommendation

- We recommend ICG-F, which has shown promise in various applications in pediatric thoracic surgery. However, its limitations in the context of nodule detection indicate a need for further prospective clinical trials using accepted standards for assessment and validation. The most reliable is solid hepatic tumor metastasis.
- This recommendation received a 93% agreement in the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

3.13. Additional Surgical applications of ICG-F

The utility of ICG-F has been reported in various other surgical domains, including head and neck surgeries [25,45,46], orthopedics [39,41,42], endocrinological interventions, and plastic and reconstructive surgeries [55]. A comprehensive review of these studies is available in Supplement 3. The limited breadth of the literature presents a pressing need for more research to assess the efficacy and safety of ICG-F in these surgical fields. However, preliminary results suggest a promising role for ICG-F potential as an adjunctive tool for enhancing the visualization of anatomical structures and assessing tissue perfusion in diverse surgical settings (Table 2).

3.13.1. Statements and observations

The expert concurs on ICG-F's significant potential in delivering real-time tissue perfusion insights across various surgical settings. Specifically, ICG-F shows potential in pediatric surgery by amplifying intraoperative clarity. Improved visualization could contribute to greater surgical precision and better decision-making,

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

Table 3
Procedural dosing Indocyanine Green Fluorescence (ICG-F) in Pediatric Surgical Patients.

Procedure	Purpose	Examples	Injection type	Injection timing	ICG dosing/age group	First detection	Duration of Fluorescence	# patients	Comments	Citations
Cholecystectomy	Anatomic visualization	Biliary disease, symptomatic cholelithiasis, acute cholecystitis, and cholangitis.	Intravenous	15h–18h pre-operatively	0.35–0.40 mg/kg | 7–16 years	Visible during surgery	Visible during surgery	50	most of the dye has accumulated in the extrahepatic duct, whereas the absence of fluorescence was typically noticeable in the liver parenchyma	Esposito, 2019, 2020, 2021;
			Intravenous	intra-operatively	1 ml of 25 mg in 10 ml H2O | 6–18 years	Within minutes, maximum absorption peak within 2h	Visible during surgery	107	ICG is excreted into the bile within minutes after intravenous injection, reaching a maximum absorption peak within 2 h.	Calabro, 2020; Shafy, 2020
Anastomosis	Perfusion Assessment	Gastro-intestinal: Hirschsprung disease, necrotizing enterocolitis, anorectal malformations, Repair of esophageal atresia	Intravenous	Intra-operatively	0.1–0.5 mg/kg	Within minutes	Minutes	137		Le-Nguyen, 2023; Numanoglu, 2011; Rentea, 2020; Shafy 2020; Meisner 2023
Hepatoblastoma, liver cell carcinoma	Tumor identification	Surgical resection, hepatic resections	Intravenous	24–96 h pre-OP	0.1–0.75 mg/kg | 5D - 12 Y	Visible during surgery	Visible during surgery	40	Zeineddin: Hepatic - Administered days before surgery to demarcate margins during liver resection	Shen, 2023; Whitlock, 2022; Souzaki, 2019; Zeineddin, 2022
Pulmonary metastases of hepatoblastoma	Tumor identification	Lung metastasectomy	Intravenous	1 Day pre-OP	0.5 mg/kg | 4 M–11 Y	Visible during surgery	Visible during surgery	26	Yoshida, 2022: Using ICG fluorescent imaging, even lesions <1 mm and located up to 10 mm in depth from the surface were expected to be detectable	Yoshida, 2022, Kitagawa, 2015
Congenital heart defects	Anatomic visualization, perfusion assessment	(1) coronary reimplants, (2) coarctations, (3) variable palliative shunts, and (4) pulmonary reconstructions, Intraoperative fluorescence angiography during coronary artery reimplantation	Intravenous OR direct injection in aortic root	intra-operatively	1.25 mg in infants (<1 yr), 2.5 mg in children (<16 years)	Within minutes	Not reported	55		Kogon, 2009; Said, 2021
Lymphatic Mapping, SLNB	Anatomic visualization	lymphovenous anastomosis, vascularized lymph node transfer, sentinel lymph node procedure, lymphaticovenous anastomosis	IV or subdermally	intra-operatively OR 1–2 day prior to Surgery (SLN lymphatic mapping, Jeremiasse, 2023)	0.25 mg - inconsistent reporting	Within minutes	Not reported	62		Chen, 2020; Jeremiasse, 2023; Mansfield, 2020; Mahira, 2015; Shibasaki, 2014
Urology	Anatomic visualization	Varicocele repairs, lymphography, partial nephrectomy, Laparoscopic partial nephrectomy, renal cyst deroofing, laparoscopic heminephrectomy	IV	intra-operatively	0.2–0.5 mg/kg | 0.8–19 years	Within minutes	Not reported	46		Esposito, 2020; Esposito, 2021; Herz, 2016
	Tumor/tumor margin identification	Nephron-sparing surgery, renal tumors	IV	1 Day pre-OP	1.25 mg/kg	Visible during surgery	Not reported	8		Abdelhafeez, 2022
Kasai Procedure	Anatomic visualization	Biliary atresia	Intravenous	1 day before surgery	0.5 mg/kg	Visible during surgery	Visible during surgery			Hirayama, 2015; Yanagi, 2019

ultimately enhancing patient outcomes. However, it is crucial to underscore that the prevailing evidence supporting these applications is of low quality.

3.13.2. Recommendation

- We recommend further research to standardize additional surgical applications and to investigate its clinical benefit.
- This recommendation received a 100% agreement in the first round of the online survey.

Level of evidence 4, Grade of Recommendation D.

3.14. ICG-F dosing: current landscape and challenges

Considerable variations in ICG-F dosing protocols emphasize the absence of uniform reporting standards. According to the product guidelines from a recognized ICG distributor,[1] the following maximum daily dosing parameters are recommended: Adults and Elderly: Up to 5 mg/kg of body weight. Adolescents (11–18 years): Up to 5 mg/kg of body weight. Children (2–11 years): Up to 2.5 mg/kg of body weight. Infants (0 months–2 years): Up to 1.25 mg/kg of body weight.

However, most research articles advocate a more conservative daily dose of 0.6 mg/kg of ICG. A notable exception is the study by Abdelhafeez et al. (2022) [107], which prescribes up to 1.5 mg/kg. Some use higher doses for non-liver lung metastasis, such as 4 mg/kg. Due to robust, evidence-driven research scarcity, the optimal dosing standard protocols still need to be determined. Table 3 presents a comprehensive outline of ICG-F dosing and application methods from studies.

3.14.1. Statements and observations

The panel unanimously agrees that a weight-based dosing methodology appears most appropriate currently. However, ideal dosages may be contingent upon specific surgical procedures and individual patient characteristics. The present research needs to be more adequate for establishing evidence-based dosing guidelines, underlining the need for further rigorous scientific studies.

3.14.2. Recommendation

- We recommend further research to standardize the technique of weight-based dosing during ICG-F applications and to utilize previously published literature as a guide.
- This recommendation received a 100% agreement was reached during the first round of the online survey.

Level of evidence 3, Grade of Recommendation C.

Table 4
Structural Framework guidelines for Adaptation and utilization of consensus guidelines for the Indocyanine Green Fluorescence (ICG-F) in Pediatric Surgical Patients.

1. Literature Review & Recommendations
- Comprehensive examination of all existing research related to ICG-F usage in pediatric patients. - Identification of standard dosing guidelines based on the literature. - Recommendations on the frequency and mode of ICG-F administration in different surgical scenarios.
2. OR Technology Awareness
- Training modules for surgical teams on the correct utilization of ICG-F technology. - Integration of ICG-F technology into regular OR protocols, ensuring consistent usage. - Periodic review and updates based on advancements in ICG-F technology.
3. Operational Notes & Documentation
- Clear documentation on the specific dosing of ICG-F used for each surgical procedure. - Machine specifics: Details of the machine or technology used to administer or visualize the ICG-F. - Captured Images: Maintenance of a visual log (securely stored) of the fluorescence patterns and observations during surgery. - Management Changes: Notes any alterations made to the surgical approach based on ICG-F observations. - Confirmation Protocols: Checklists or procedures in place to verify and validate the successful application and visualization of ICG-F during surgery.
4. Safety Protocols
- Monitoring for any adverse reactions in pediatric patients' post-surgery. - Protocol for immediate intervention in case of unexpected reactions or complications related to ICG-F. - Ongoing assessment of long-term effects or potential risks associated with ICG-F usage in pediatric populations.
5. Feedback and Continuous Improvement
- Collection of feedback from surgical teams on the ease of use, effectiveness, and potential improvements in ICG-F guidelines. - Periodic reviews of the guidelines based on new research, feedback, and technological advancements. - Commitment to refining and enhancing the guidelines for improving pediatric patient outcomes.
6. Stakeholder Collaboration
- Collaborative efforts with ICG-F technology manufacturers to understand the nuances of the technology and ensure its best application. - Engaging surgeons, anesthesiologists, peri-operative leadership, and other stakeholders in the discussion to ensure a holistic approach to using ICG-F in surgeries.
7. Patient and Parent Education
- Informative sessions or materials for parents and caregivers on the benefits, procedure, and safety of ICG-F usage. - Ensuring informed consent by explaining the role of ICG-F in the surgical procedure and any associated risks or benefits.

4. Discussion

Our study delineates the consensus on applying indocyanine green fluorescence (ICG-F) in pediatric surgery, providing a collective expert opinion on its efficacy and safety. The low quality of evidence is validated by using an anonymous Delphi voting method to identify the best-standardized practice amongst a group of multi-center international specialists. Through the Delphi method, we found a strong agreement on ICG-F's utility in enhancing intraoperative visualization—a critical aspect that aligns with its reported ability to improve surgical precision and patient outcomes. The impact of this consensus is significant, suggesting that incorporating ICG-F into pediatric surgical protocols may lead to improved procedural accuracy and reduced complication rates.

Despite the promising applications of ICG-F, interpretations of the data warrant caution. While the results corroborate the advantages of ICG-F, such as aiding in tumor delineation and assessing tissue viability, these findings derive from a heterogeneous mix of studies, including case reports and small series. This variability underscores the need for standardized methodologies to solidify the evidence base in future studies.

ICG-F provides enhanced real-time imaging, which may contribute to improved surgical outcomes. This capability stems from its unique ability to fluoresce in the near-infrared range when excited by light of specific wavelengths. It allows it to provide real-time visualization of critical structures and processes during surgery.

[1] https://diagnosticgreen.com/row/product-information/ [29.Sept.2023].

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

Compared with findings in the adult literature, it is evident that the use of ICG-F in pediatric surgery is still emerging, with many articles being case studies or small series reports. However, the consistent reporting of positive outcomes across a variety of surgical specialties indicates a promising trend. The use of ICG-F for tumor visualization aligns with findings from other research that suggest its potential for delineating tumor boundaries and aiding surgical planning. Similarly, our findings on perfusion assessment are supported by studies that have reported ICG-F's usefulness in determining tissue viability, thus aiding surgical decision-making.

Challenges exist when applying consensus-driving guidelines. Table 4 provides a structural framework for ICG-F utilization rooted in the consensus statements. The results of this review can potentially be generalized across other pediatric surgical contexts beyond those identified in the reviewed articles. ICG-F might also be useful in other disease states where visualization of anatomical structures or perfusion status is essential and in different populations such as adult patients or those with different co-morbid conditions. Furthermore, there are additional fluorescence-guided surgery techniques either available [108] or under development for the foreseeable future [109].

Future research should focus on large-scale, prospective trials that employ consistent dosing protocols. Such studies would not only solidify the current consensus but could also extend the applicability of ICG-F to other patient demographics and surgical contexts. Moreover, adapting ICG-F usage to suit individual patient characteristics and specific surgical needs will be an essential step toward personalized surgical care.

5. Limitations

The consensus process highlighted several limitations: the diversity in study designs and the lack of large-scale trials limit the strength of the evidence. Additionally, the variability in ICG-F dosing and reporting protocols across the literature underscores the necessity for standardized guidelines. These limitations are particularly evident in delineating pediatric solid tumor resection margins compared to standard care. Most studies have focused on ICG's ability to identify tumors and potentially visualize non-detectable metastases or guide the extent of resection visually at the commencement of surgery. These issues underline the preliminary nature of the consensus and the need for ongoing evaluation as further evidence emerges.

Pediatric studies on ICG-F are particularly heterogeneous regarding age, utilization, and consistent outcome reporting. There is no quantifiable data from the intraoperative evaluation of fluorescence to make reliable comparisons. Additionally, the number of patients needed to treat (NNT) for ICG-F utilization is often high, indicating that many patients must be treated to achieve one more beneficial outcome than a control group. The NNT to prevent complications, such as common bile duct injury during laparoscopic ICG-guided cholecystectomy, has not been fully elucidated, and data in available studies has not been recorded in standardized manners, even if it changes or confirms intraoperative decision-making. Thus, while ICG is a useful adjunct in surgery, it does not yet provide conclusive answers to these comparative questions and raises questions about the cost-effectiveness and practical value of using ICG-F in rare cases.

Efforts to quantify perfusion based on fluorescent patterns are subjective, although ongoing, and scoring systems may be required to standardize this process. Additionally, operative reports must provide detailed reporting on dosing, utilization, timing of dose to fluorescence, and any changes in operative management due to ICG-F use. As seen in the case of non-hepatic malignancies, ICG-F fails to adequately target a wide range of pathologies that would benefit from enhanced intraoperative guidance. Comparative studies between ICG-F and non-ICG-F cases are also lacking, with much of the current literature comprising case reports underscoring the need for more comprehensive and comparative studies.

6. Conclusion

In summary, this consensus statement on ICG-F use in pediatric surgery is a foundational reference highlighting its potential benefits. While promising, the current evidence calls for further investigation to establish comprehensive, evidence-based guidelines. The collective expert opinion, nevertheless, recognizes ICG-F as a valuable tool in pediatric surgical practice, with the potential to substantially elevate the standard of care.

Financial support

None.

Conflict of interest

All authors have no disclosures or conflicts of interest.

Acknowledgements

Keri Swaggart, Children's Mercy — Kansas City Librarian.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2024.07.042.

References

[1] Reinhart MB, Huntington CR, Blair LJ, Heniford BT, Augenstein VA. Indocyanine green. Surg Innovat 2015;23(2):166–75.
[2] Yannuzzi LA. Indocyanine green angiography: a perspective on use in the clinical setting. Am J Ophthalmol 2011;151(5):745–751.e1.
[3] Le-Nguyen A, O'Neill Trudeau M, Dodin P, Keezer MR, Faure C, Piché N. The use of indocyanine green fluorescence angiography in pediatric surgery: a systematic review and narrative analysis. Front Pediatr 2021;9:736242.
[4] Hamel C, Michaud A, Thuku M, Affengruber L, Skidmore B, Nussbaumer-Streit B, et al. Few evaluative studies exist examining rapid review methodology across stages of conduct: a systematic scoping review. J Clin Epidemiol 2020;126:131–40.
[5] Hamel C, Michaud A, Thuku M, Skidmore B, Stevens A, Nussbaumer-Streit B, et al. Defining Rapid Reviews: a systematic scoping review and thematic analysis of definitions and defining characteristics of rapid reviews. J Clin Epidemiol 2021;129:74–85.
[6] Smela B, Toumi M, Świerk K, Francois C, Biernikiewicz M, Clay E, et al. Rapid literature review: definition and methodology. J Mark Access Health Policy 2023;11(1):2241234.
[7] Atkins D, Best D, Briss PA, Eccles M, Falck-Ytter Y, Flottorp S, et al. Grading quality of evidence and strength of recommendations. BMJ 2004;328(7454):1490.
[8] Diamond IR, Grant RC, Feldman BM, Pencharz PB, Ling SC, Moore AM, et al. Defining consensus: a systematic review recommends methodologic criteria for reporting of Delphi studies. J Clin Epidemiol 2014;67(4):401–9.
[9] Meira J, Marques ML, Falcão-Reis F, Rebelo Gomes E, Carneiro Â. Immediate reactions to fluorescein and indocyanine green in retinal angiography: review of literature and proposal for patient's evaluation. Clin Ophthalmol 2020;14:171–8.
[10] Breuking EA, van Varsseveld OC, Harms M, Tytgat SHAJ, Hulscher JBF, Ruiterkamp J. Safety and feasibility of indocyanine green fluorescence angiography in pediatric gastrointestinal surgery: a systematic review. J Pediatr Surg 2023;58(8):1534–42.
[11] Zeineddin S, Linton S, Inge M, De Boer C, Hu A, Goldstein SD, et al. Fluorescence-guided surgery: national trends in adoption and application in pediatric surgery. J Pediatr Surg 2023;58(4):689–94.
[12] Shibasaki J, Hara H, Mihara M, Adachi S, Uchida Y, Itani Y. Evaluation of lymphatic dysplasia in patients with congenital pleural effusion and ascites using indocyanine green lymphography. J Pediatr 2014;164(5):1116–11120.e1.
[13] Shirotsuki R, Uchida H, Tanaka Y, Shirota C, Yokota K, Murase N, et al. Novel thoracoscopic navigation surgery for neonatal chylothorax using

indocyanine-green fluorescent lymphography. J Pediatr Surg 2018;53(6):1246–9.
[14] Abdelhafeez AH, Mothi SS, Pio L, Mori M, Santiago TC, McCarville MB, et al. Feasibility of indocyanine green-guided localization of pulmonary nodules in children with solid tumors. Pediatr Blood Cancer 2023;70(10):e30437 [e].
[15] Abdelhafeez AH, Murphy AJ, Brennan R, Santiago TC, Lu Z, Krasin MJ, et al. Indocyanine green–guided nephron-sparing surgery for pediatric renal tumors. J Pediatr Surg 2022;57(9):174–8.
[16] Asayama B, Sato K, Fukui T, Okuma M, Nakagaki Y, Nakagaki Y, et al. Skull bone tumor resection with intraoperative indocyanine green fluorescence imaging: a series of four surgical cases. Interdisciplinary Neurosurgery 2017;9:8–13.
[17] Chen-Yoshikawa TF, Hatano E, Yoshizawa A, Date H. Clinical application of projection mapping technology for surgical resection of lung metastasis. Interact Cardiovasc Thorac Surg 2017;25(6):1010–1.
[18] Chung PHY, Chok KSH, Wong KKY. Indocyanine green fluorescence-assisted laparoscopic hepatectomy for hepatocellular carcinoma in a pre-adolescent girl: a case report. Hong Kong Med J 2020;26(4):342–4.
[19] Delgado-Miguel C, Estefanía K, San Basilio M, Hernández Oliveros F. Indocyanine green navigation in minimally invasive resection of multiple metachronous pulmonary metastases of hepatoblastoma. Thorac Cancer 2023;14(5):528–32.
[20] Fung CH, Lau CT, Wong KKY. Indocyanine green fluorescence-guided pulmonary wedge resection in a child: a case report. Hong Kong Med J 2020;26(4):345–7.
[21] Harris ACV, Choudhury S, Pachl M. Early results of minimally invasive fluorescent guided pediatric oncology surgery with delivery of indocyanine green during induction of anesthesia. Photodiagnosis Photodyn Ther 2023;42:103639.
[22] Kitagawa N, Shinkai M, Mochizuki K, Usui H, Miyagi H, Nakamura K, et al. Navigation using indocyanine green fluorescence imaging for hepatoblastoma pulmonary metastases surgery. Pediatr Surg Int 2015;31(4):407–11.
[23] Komatsu S, Terui K, Nakata M, Shibata R, Oita S, Kawaguchi Y, et al. Combined use of three-dimensional construction and indocyanine green-fluorescent imaging for resection of multiple lung metastases in hepatoblastoma. Children 2022;9(3):376.
[24] Mitani Y, Kubota A, Ueno M, Takifuji K, Watanabe T, Hayami S, et al. Real-time identification of hepatoblastoma using a near infrared imaging with indocyanine green. Journal of Pediatric Surgery Case Reports 2014;2(4):180–3.
[25] Richard C, White S, Williams R, Zaghloul T, Helmig S, Sheyn A, et al. Indocyanine green near infrared-guided surgery in children, adolescents, and young adults with otolaryngologic malignancies. Auris Nasus Larynx 2023;50(4):576–85.
[26] Shen Q, Liu X, Pan S, Li T, Zhou J. Effectiveness of indocyanine green fluorescence imaging in resection of hepatoblastoma. Pediatr Surg Int 2023;39(1).
[27] Shirota C, Hinoki A, Takahashi M, Tanaka Y, Tainaka T, Sumida W, et al. New navigation surgery for resection of lymphatic malformations using indocyanine green fluorescence imaging. Am J Case Rep 2017;18:529–31.
[28] Sound S, Okoh AK, Bucak E, Yigitbas H, Dural C, Berber E. Intraoperative tumor localization and tissue distinction during robotic adrenalectomy using indocyanine green fluorescence imaging: a feasibility study. Surg Endosc 2015;30(2):657–62.
[29] Souzaki R, Kawakubo N, Matsuura T, Yoshimaru K, Koga Y, Takemoto J, et al. Navigation surgery using indocyanine green fluorescent imaging for hepatoblastoma patients. Pediatr Surg Int 2019;35(5):551–7.
[30] Takahashi N, Yamada Y, Hoshino K, Kawaida M, Mori T, Abe K, et al. Living donor liver Re-transplantation for recurrent hepatoblastoma in the liver graft following complete eradication of peritoneal metastases under indocyanine green fluorescence imaging. Cancers 2019;11(5):730.
[31] Tsuzuki S, Aihara Y, Eguchi S, Amano K, Kawamata T, Okada Y. Application of indocyanine green (ICG) fluorescence for endoscopic biopsy of intraventricular tumors. Child's Nerv Syst 2013;30(4):723–6.
[32] Whitlock RS, Patel KR, Yang T, Nguyen HN, Masand P, Vasudevan SA. Pathologic correlation with near infrared-indocyanine green guided surgery for pediatric liver cancer. J Pediatr Surg 2022;57(4):700–10.
[33] Yamada Y, Ohno M, Fujino A, Kanamori Y, Irie R, Yoshioka T, et al. Fluorescence-guided surgery for hepatoblastoma with indocyanine green. Cancers 2019;11(8):1215.
[34] Yamamichi T, Oue T, Yonekura T, Owari M, Nakahata K, Umeda S, et al. Clinical application of indocyanine green (ICG) fluorescent imaging of hepatoblastoma. J Pediatr Surg 2015;50(5):833–6.
[35] Yoshida M, Tanaka M, Kitagawa N, Nozawa K, Shinkai M, Goto H, et al. Clinicopathological study of surgery for pulmonary metastases of hepatoblastoma with indocyanine green fluorescent imaging. Pediatr Blood Cancer 2021;69(7).
[36] Lim C, Vibert E, Azoulay D, Salloum C, Ishizawa T, Yoshioka R, et al. Indocyanine green fluorescence imaging in the surgical management of liver cancers: current facts and future implications. J Vis Surg 2014;151(2):117–24.
[37] Qiu R, Wu Y, Su J, Chen L, Liao M, Zhao Z, et al. Deploying indocyanine green fluorescence-guided navigation system in precise laparoscopic resection of pediatric hepatoblastoma. Cancers 2022;14(24).
[38] Arichi N, Mitsui Y, Ogawa K, Nagami T, Nakamura S, Hiraoka T, et al. Intraoperative fluorescence vascular imaging using indocyanine green for assessment of transplanted kidney perfusion. Transplant Proc 2014;46(2):342–5.
[39] Aung T, Heidekrueger PI, Geis S, Von Kunow F, Taeger C, Strauss C, et al. A novel indication for indocyanine green (ICG): intraoperative monitoring of limb and sciatic nerve perfusion during rotationplasty for sarcoma patients. Clin Hemorheol Microcirc 2019;70(4):441–7.
[40] Castro-e-Silva O, Sankarankutty AK, Correa RB, Ferreira J, Vollet Filho JD, Kurachi C, et al. Autofluorescence spectroscopy in liver transplantation: preliminary results from a pilot clinical study. Transplant Proc 2008;40(3):722–5.
[41] Cleveland CPTA, Abdelgawad A, Cook J, Pirela-Cruz M. Use of indocyanine green fluorescent dye video angiography in orthopaedic trauma: a pilot study. J Surg Orthop Adv 2013;22(4):310–5.
[42] Connolly PH, Meltzer AJ, Spector JA, Schneider DB. Indocyanine green angiography aids in prediction of limb salvage in vascular trauma. Ann Vasc Surg 2015;29(7):1453.e1. e4.
[43] Fernández-Bautista B, Mata DP, Parente A, Pérez-Caballero R, De Agustín JC. First experience with fluorescence in pediatric laparoscopy. Eur J Pediatr Surg Rep 2019;7(1):e43–6.
[44] Figueroa R, Golse N, Alvarez FA, Ciacio O, Pittau G, Sa Cunha A, et al. Indocyanine green fluorescence imaging to evaluate graft perfusion during liver transplantation. HPB 2019;21(4):387–92.
[45] Fried FW, Beier JP, Bohr C, Iro H, Horch RE, Arkudas A. Free latissimus dorsi myocutaneous flap in a 6-month-old child for reconstruction of a temporal fossa defect after teratoma resection. Ann Plast Surg 2019;82(1):62–3.
[46] Hinchcliff KM, Yao A, Taub PJ. Laser-assisted indocyanine green imaging to assess perfusion of scalp closure in an infant. J Craniofac Surg 2013;24(6):2004–6.
[47] Hori S, Kashiwazaki D, Akioka N, Hayashi T, Hori E, Umemura K, et al. Surgical anatomy and preservation of the middle meningeal artery during bypass surgery for moyamoya disease. Acta Neurochir 2014;157(1):29–36.
[48] Horie N, Fukuda Y, Izumo T, Hayashi K, Suyama K, Nagata I. Indocyanine green videoangiography for assessment of postoperative hyperperfusion in moyamoya disease. Acta Neurochir 2014;156(5):919–26.
[49] Iinuma Y, Hirayama Y, Yokoyama N, Otani T, Nitta K, Hashidate H, et al. Intraoperative near-infrared indocyanine green fluorescence angiography (NIR-ICG AG) can predict delayed small bowel stricture after ischemic intestinal injury: report of a case. J Pediatr Surg 2013;48(5):1123–8.
[50] Ishikawa K, Sasaki S, Furukawa H, Nagao M, Iwasaki D, Saito N, et al. Preliminary experience with intraoperative near-infrared fluorescence imaging in percutaneous sclerotherapy of soft-tissue venous malformations. Dermatol Surg 2013;39(6):907–12.
[51] Kaneshi Y, Shibasaki J, Aida N, Shimokaze T, Toyoshima K. Indocyanine green lymphography for congenital lymphatic dysplasia with tuberous sclerosis complex: a case report. Pediatr Int 2020;62(2):234–6.
[52] Kato M, Watanabe S, Iida T, Watanabe A, Megumi F. Peri-orbital lymphangioma treated by lymphatic-venous anastomosis with indocyanine green lymphography analysis. Journal of Pediatric Surgery Case Reports 2017;23:9–14.
[53] Kisaoglu A, Demiryilmaz I, Dandin O, Ozkan O, Aydinli B. Management of reperfusion deficiency with indocyanine green fluorescence imaging during deceased donor liver transplantation in a pediatric recipient. HPB 2020;22(4):633.
[54] Le-Nguyen A, Bourque CJ, Trudeau MON, Ducruet T, Faure C, Piché N. Indocyanine green fluorescence angiography in pediatric intestinal resections: a first prospective mixed methods clinical trial. J Pediatr Surg 2023;58(1):82–8.
[55] Martins DB, Farias-Eisner G, Mandelbaum RS, Hoang H, Bradley JP, Lee JC. Intraoperative indocyanine green laser angiography in pediatric autologous ear reconstruction. Plast Reconstr Surg Glob Open 2016;4(5):e709–.
[56] Meisner JW, Kamran A, Staffa SJ, Mohammed S, Yasuda JL, Ngo P, et al. Qualitative features of esophageal fluorescence angiography and anastomotic outcomes in children. J Pediatr Surg 2023;58(7):1359–67.
[57] Numanoglu A, Millar AJW. Necrotizing enterocolitis: early conventional and fluorescein laparoscopic assessment. J Pediatr Surg 2011;46(2):348–51.
[58] Onishi S, Muto M, Yamada K, Murakami M, Kedoin C, Nagano A, et al. Feasibility of delayed anastomosis for long gap esophageal atresia in the neonatal period using internal traction and indocyanine green-guided near-infrared fluorescence. Asian J Endosc Surg 2022;15(4):877–81.
[59] Paraboschi I, Gnech M, Minoli DG, De Marco EA, Parente G, Mantica G, et al. Indocyanine green (ICG)-Guided onlay preputial island flap urethroplasty for the single-stage repair of hypospadias in children: a case report. Int J Environ Res Publ Health 2023;20(13):6246.
[60] Rentea RM, Halleran DR, Ahmad H, Sanchez AV, Gasior AC, McCracken K, et al. Preliminary use of indocyanine green fluorescence angiography and value in predicting the vascular supply of tissues needed to perform cloacal, anorectal malformation, and Hirschsprung reconstructions. Eur J Pediatr Surg 2019;30(6):505–11.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042

[61] Sugimoto T, Park Y-S, Nakagawa I, Nishimura F, Motoyama Y, Nakase H. Effectiveness of intraoperative indocyanine green videoangiography in direct surgical treatment of pediatric intracranial pial arteriovenous fistula. J Neurosurg Pediatr 2015;15(1):55–9.
[62] Sugita K, Onishi S, Kedoin C, Matsui M, Murakami M, Yano K, et al. A safe and effective laparoscopic Ladd's procedure technique involving the confirmation of mesenteric vascular perfusion by fluorescence imaging using indocyanine green: a case report of an infant. Asian J Endosc Surg 2022;15(2):410–4.
[63] Takagi Y, Sawamura K, Hashimoto N, Miyamoto S. Evaluation of serial intraoperative surgical microscope-integrated intraoperative near-infrared indocyanine green videoangiography in patients with cerebral arteriovenous malformations. Operative Neurosurgery 2012;70:ons34–43.
[64] Tomioka YK, Narushima M, Yamashita S, Ito A, Okazaki M. Foot web space transfer for congenital syndactyly. Plast Reconstr Surg Glob Open 2020;8(12):e3292–.
[65] Vogt P, Bauer E, Graves K. Novadaq Spy™ intraoperative imaging system - current status. Thorac Cardiovasc Surg 2003;51(1):49–51.
[66] Yada K, Migita M, Nakamura R, Abe S, Matsufuji H. Indocyanine green fluorescence during pediatric stoma closure. Journal of Pediatric Surgery Case Reports 2020;61:101595.
[67] Bada-Bosch I, Mata DP, de la Torre M, Ordóñez J, Blanco MD, de Agustin J. Laparoscopic partial splenectomy assisted by fluorescence in a 13-year-old girl. Eur J Pediatr Surg Rep 2020;8(1):e81–5.
[68] Bryant MK, Marulanda K, Phillips MR. Laparoscopic double cholecystectomy in a pediatric patient for gallbladder duplication. Am Surg 2020;86(11):1531–4.
[69] Calabro KA, Harmon CM, Vali K. Fluorescent cholangiography in laparoscopic cholecystectomy and the use in pediatric patients. J Laparoendosc Adv Surg Tech 2020;30(5):586–9.
[70] Esposito C, Alberti D, Settimi A, Pecorelli S, Boroni G, Montanaro B, et al. Indocyanine green (ICG) fluorescent cholangiography during laparoscopic cholecystectomy using RUBINA™ technology: preliminary experience in two pediatric surgery centers. Surg Endosc 2021;35(11):6366–73.
[71] Esposito C, Autorino G, Coppola V, Esposito G, Paternoster M, Castagnetti M, et al. Technical standardization of ICG near-infrared fluorescence (NIRF) laparoscopic partial nephrectomy for duplex kidney in pediatric patients. World J Urol 2021;39(11):4167–73.
[72] Esposito C, Coppola V, Del Conte F, Cerulo M, Esposito G, Farina A, et al. Near-Infrared fluorescence imaging using indocyanine green (ICG): emerging applications in pediatric urology. J Pediatr Urol 2020;16(5):700–7.
[73] Esposito C, Settimi A, Cerulo M, Escolino M. Efficacy of indocyanine green (ICG) fluorescent cholangiography to improve intra-operative visualization during laparoscopic cholecystectomy in pediatric patients: a comparative study between ICG-guided fluorescence and standard technique. Surg Endosc 2021;36(6):4369–75.
[74] Esposito C, Soria-Gondek A, Castagnetti M, Cerulo M, Del Conte F, Esposito G, et al. Laparoscopic or robotic deroofing guided by indocyanine green fluorescence and perirenal fat tissue wadding technique of pediatric simple renal cysts. J Laparoendosc Adv Surg Tech 2020;30(4):471–6.
[75] Esposito C, Turrà F, Del Conte F, Izzo S, Gargiulo F, Farina A, et al. Indocyanine green fluorescence lymphography: a new technique to perform lymphatic sparing laparoscopic palomo varicocelectomy in children. J Laparoendosc Adv Surg Tech 2019;29(4):564–7.
[76] Graves C, Ely S, Idowu O, Newton C, Kim S. Direct gallbladder indocyanine green injection fluorescence cholangiography during laparoscopic cholecystectomy. J Laparoendosc Adv Surg Tech 2017;27(10):1069–73.
[77] Hirayama Y, Iinuma Y, Yokoyama N, Otani T, Masui D, Komatsuzaki N, et al. Near-infrared fluorescence cholangiography with indocyanine green for biliary atresia. Real-time imaging during the Kasai procedure: a pilot study. Pediatr Surg Int 2015;31(12):1177–82.
[78] Kobayashi Y, Kawaguchi Y, Kobayashi K, Mori K, Arita J, Sakamoto Y, et al. Portal vein territory identification using indocyanine green fluorescence imaging: technical details and short-term outcomes. J Surg Oncol 2017;116(7):921–31.
[79] Kogon B, Fernandez J, Kanter K, Kirshbom P, Vincent B, Maher K, et al. The role of intraoperative indocyanine green fluorescence angiography in pediatric cardiac surgery. Ann Thorac Surg 2009;88(2):632–6.
[80] Lemoine CP, Lautz TB, Superina R. Indocyanine green fluorescence imaging as an adjunct for the localization of a bile leak after split liver transplantation. Pediatr Transplant 2022;27(3).
[81] Masuya R, Nakame K, Tahira K, Kai K, Hamada T, Yano K, et al. Laparoscopic dome resection for pediatric nonparasitic huge splenic cyst safely performed using indocyanine green fluorescence and percutaneous needle grasper. Asian J Endosc Surg 2022;15(3):693–6.
[82] Mayorga-Buiza MJ, Rivero-Garvia M, Márquez-Rivas J. Microvascular fluorescence in spinal cord repair. World Neurosurgery 2019;125:245–6.
[83] Pandey P, Ambekar S, Babu A, Devi I. Intraoperative assessment of STA-MCA bypass patency using near-infrared indocyanine green video-angiography: a preliminary study. Neurol India 2012;60(6):604.
[84] Pourmoghadam KK, Bunnell APM, O'Brien MC, DeCampli WM. Avoiding coronary injury in congenital heart surgery by laser-assisted indocyanine green dye imaging. World Journal for Pediatric and Congenital Heart Surgery 2014;5(2):326–9.
[85] Tanabe N, Yamamoto S, Kashiwazaki D, Akioka N, Kuwayama N, Noguchi K, et al. Indocyanine green visualization of middle meningeal artery before craniotomy during surgical revascularization for moyamoya disease. Acta Neurochir 2017;159(3):567–75.
[86] Tomita K, Kageyama S, Hanada E, Yoshida T, Okinaka Y, Kubota S, et al. Indocyanine green angiography-assisted laparoendoscopic single-site varicocelectomy. Urology 2017;106:221–5.
[87] Troisi RI, Elsheikh YM, Shagrani MA, Broering D. First fully laparoscopic donor hepatectomy for pediatric liver transplantation using the indocyanine green near-infrared fluorescence imaging in the Middle East: a case report. Ann Saudi Med 2014;34(4):354–7.
[88] Ueba T, Abe H, Matsumoto J, Higashi T, Inoue T. Efficacy of indocyanine green videography and real-time evaluation by FLOW 800 in the resection of a spinal cord hemangioblastoma in a child. J Neurosurg Pediatr 2012;9(4):428–31.
[89] Yanagi Y, Yoshimaru K, Matsuura T, Shibui Y, Kohashi K, Takahashi Y, et al. The outcome of real-time evaluation of biliary flow using near-infrared fluorescence cholangiography with Indocyanine green in biliary atresia surgery. J Pediatr Surg 2019;54(12):2574–8.
[90] Esposito C, Settimi A, Del Conte F, Cerulo M, Coppola V, Farina A, et al. Image-guided pediatric surgery using indocyanine green (ICG) fluorescence in laparoscopic and robotic surgery. Front Pediatr 2020;8:314.
[91] Esposito C, Borgogni R, Autorino G, Cerulo M, Carulli R, Esposito G, et al. Applications of indocyanine green-guided near-infrared fluorescence imaging in pediatric minimally invasive surgery urology: a narrative review. J Laparoendosc Adv Surg Tech 2022;32(12):1280–7.
[92] Cheng MH, Liu TTF. Lymphedema microsurgery improved outcomes of pediatric primary extremity lymphedema. Microsurgery 2020;40(7):766–75.
[93] Drobot A, Ganam S, Karra N, Bickel A, Abu Shakra I, Kakiashvili E. Resection of an axillary macrocystic lymphatic malformation in a 14-year-old girl using intraoperative indocyanine green lymphography. J Vasc Surg: Venous and Lymphatic Disorders 2021;9(2):504–7.
[94] Greives MR, Aldrich MB, Sevick-Muraca EM, Rasmussen JC. Near-infrared fluorescence lymphatic imaging of a toddler with congenital lymphedema. Pediatrics 2017;139(4):e20154456.
[95] Jeremiasse B, van Scheltinga CEJT, Smeele LE, Tolboom N, Wijnen MHWA, van der Steeg AFW. ASO visual abstract: sentinel lymph node procedure in pediatric patients with melanoma, squamous cell carcinoma or sarcoma using near-infrared fluorescence imaging with indocyanine green: a feasibility trial. Ann Surg Oncol 2023;30(4):2399–400.
[96] Kato M, Watanabe S, Iida T, Watanabe A. Flow pattern classification in lymphatic malformations by indocyanine green lymphography. Plast Reconstr Surg 2019;143(3):558e. 64e.
[97] Mansfield SA, Murphy AJ, Talbot L, Prajapati H, Maller V, Pappo A, et al. Alternative approaches to retroperitoneal lymph node dissection for paratesticular rhabdomyosarcoma. J Pediatr Surg 2020;55(12):2677–81.
[98] Mihara M, Hara H, Shibasaki J, Seki Y, Hayashi A, Iida T, et al. Indocyanine green lymphography and lymphaticovenous anastomosis for generalized lymphatic dysplasia with pleural effusion and ascites in neonates. Ann Vasc Surg 2015;29(6):1111–22.
[99] Ogata F, Narushima M, Mihara M, Azuma R, Morimoto Y, Koshima I. Intraoperative lymphography using indocyanine green dye for near-infrared fluorescence labeling in lymphedema. Ann Plast Surg 2007;59(2):180–4.
[100] Otake K, Uchida K, Inoue M, Koike Y, Narushima M, Kusunoki M. Use of computed tomography-lymphangiography with direct injection of water-soluble contrast medium to identify the origin of chylous ascites. J Vasc Surg: Venous and Lymphatic Disorders 2015;3(1):90–3.
[101] Tan IC, Balaguru D, Rasmussen JC, Guilliod R, Bricker JT, Douglas WI, et al. Investigational lymphatic imaging at the bedside in a pediatric postoperative chylothorax patient. Pediatr Cardiol 2014;35(7):1295–300.
[102] Safiejko K, Tarkowski R, Kozlowski TP, Koselak M, Jachimiuk M, Tarasik A, et al. Safety and efficacy of indocyanine green in colorectal cancer surgery: a systematic review and meta-analysis of 11,047 patients. Cancers 2022;14(4):1036.
[103] Herz D, DaJusta D, Ching C, McLeod D. Segmental arterial mapping during pediatric robot-assisted laparoscopic heminephrectomy: a descriptive series. J Pediatr Urol 2016;12(4):266.e1. e6.
[104] Pachl MJ. Fluorescent guided lymph node harvest in laparoscopic Wilms nephroureterectomy. Urology 2021;158:189–92.
[105] Lehner M, Esslinger P, Szavay P. A surgical first: application of indocyanine green fluorescence imaging for endoscopic third ventriculostomy in an infant. J Biotechnol Biomed 2024;7:221–4.
[106] Pham KT, Balaguru D, Tammisetti VS, Guevara CJ, Rasmussen JC, Zvavanjanja RC, et al. Multimodality lymphatic imaging of postoperative chylothorax in an infant with Noonan syndrome: a case report. Eur J Med Res 2020;25(1):55.
[107] Abdelhafeez AH, Davidoff AM, Murphy AJ, Arul GS, Pachl MJ. Fluorescence-guided lymph node sampling is feasible during up-front or delayed nephrectomy for Wilms tumor. J Pediatr Surg 2022;57(12):920–5.
[108] Ott KC, Hu A, Gong EM, Lautz TB, Grabowski JE, Goldstein SD. Use of near infrared ureteral stent fibers for neonatal colorectal operations. Surg Innovat 2022;29(4):550–1.
[109] Predina JD, Newton A, Deshpande C, Low P, Singhal S. Utilization of targeted near-infrared molecular imaging to improve pulmonary metastasectomy of osteosarcomas. J Biomed Opt 2018;23(1):1–4.

Please cite this article as: Szavay PO et al., Clinical Consensus Statement on the Use of Indocyanine Green Fluorescence-guided Surgery in Pediatric Patients, Journal of Pediatric Surgery, https://doi.org/10.1016/j.jpedsurg.2024.07.042