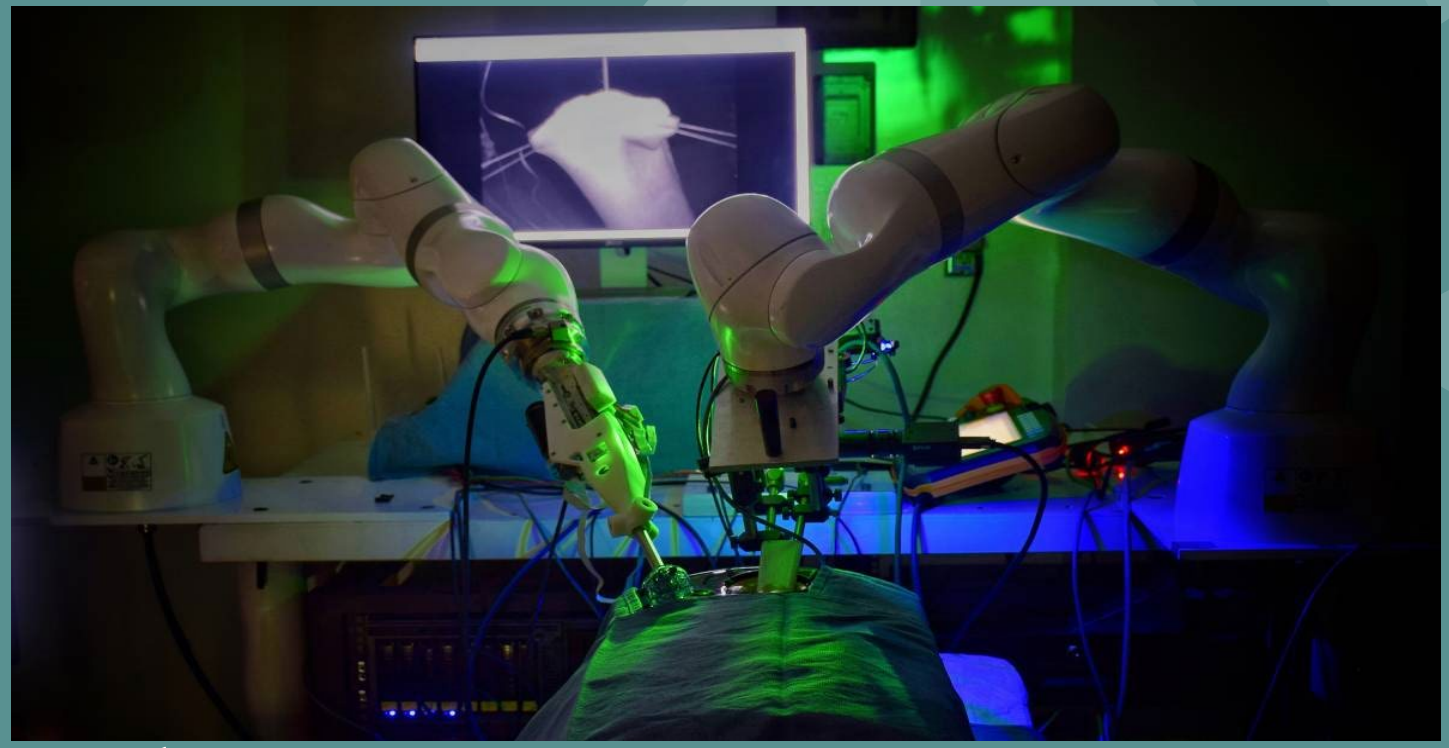
Fluorescence Guided Robotic Surgery
A Literature Review



Researchers:

Jousephine Araya, Jodie Thane, Joel Bascombe, Leopold Choi, Brian Johnson & Ragavendiran Lav

Mentor:

Dr. Alexey Pryakhin MD, PhD

SAINT JAMES
SCHOOL OF MEDICINE
Your Future. Our Promise.

Objective

The objective of this literature review is to investigate if the use of fluorescence improves the robotic-guided surgical outcomes for complete tumor excision for patients with malignancies with minimal injury to healthy adjacent tissues.

Fluorescence and DaVinci

Fluorescence

- Fluorescence and its guided robotic approaches have aided in the recognition of vascular anatomy, evaluation of organ and tissue perfusion, visualization of biliary anatomy, identification of lymph nodes, identification of specialized tissue, identification of lesions based on vascular and metabolic pattern, and adequate resection of tumors.
- Use of indicator markers such as Indocyanine Green (ICG), 5-aminolevulinic acid (5-ALA)-induced fluorescence, and protoporphyrins (PpIX).

DaVinci

- Robotic surgery/robotic-assisted surgery is a novel minimally invasive surgical technique.
- The use of robotics began in the early 1980s with the first documented surgery using the Unimation Programmable Universal Manipulation Arm (PUMA) 200 for a brain needle biopsy.
- There have been several iterations and advancements of robotics with the modern-day Da Vinci Si HD and Da Vinci Xi that improved resolution, extended reach, and added the capability of fluorescent imaging

Design and Methods

- Key text words for the search “robotic surgery” with boolean operators “AND”, “secondary malignancy”, “excision”, “oncology”, “cancer”, “tumor incisions”, “5-Aminolevulinic acid (5-ALA)”.“Protoporphyrin IV (PpIx)”, “Isocyanine Green (ICG)”, and “Methylene blue”.
- Systematic literature review through the SJSM library using PubMed, EBSCO, and Google Scholar.
- Literature search criteria included papers newer than 2010, scholarly and peer-reviewed papers, the use of specific fluorescent dye, and articles only published in the English language.
- After the accumulation of adequate articles, each of the articles was equally split among the members to evaluate.
- From there each member did a detailed analysis and literature review of the articles that were assigned to them.
- Finally, all of the literature reviews were combined and formatted to form the research paper.

Procedures in which Fluorescence-Guided Robotic Surgery was used

- Lymphadenectomy
- Colorectal and hepatobiliary surgery
- Laparoscopic adrenalectomy
- Laparoscopic partial nephrectomy
- Colon cancer oncology
- Colon resection
- Phrenic nerve thymectomy
- Tumor ablation in neurosurgery

Clinical Applications

- Indocyanine green (ICG) is a water-soluble dye that fluoresces green when excited by light in the near-infrared spectrum. Due to the non-toxic, nonradioactive properties, and high safety index, it gained Food and Drug Administration (FDA) approval in 1959 for both intravenous and interstitial administration.
- In a 2015 study by *The University of Illinois Hospital and Health Sciences System*, researchers looked at the ability to recognize the splenic artery and vein during distal pancreatectomy when visualization was blocked by a tumor and/or inflammation. The research showed that identification of major vessels could be difficult in those cases.
- A 10mg dose of ICG was injected. The median time of visualization after injection was 37.5 sec, and lasted for 1–2 min. The authors reported that NIF helped in identifying small communicating arteries between the gastroepiploic artery and the first short gastric artery. It also aided in the recognition of vessels between the small gastric arteries that would have otherwise been unrecognized. One limit of this method was the reduced visualization in obese patients.

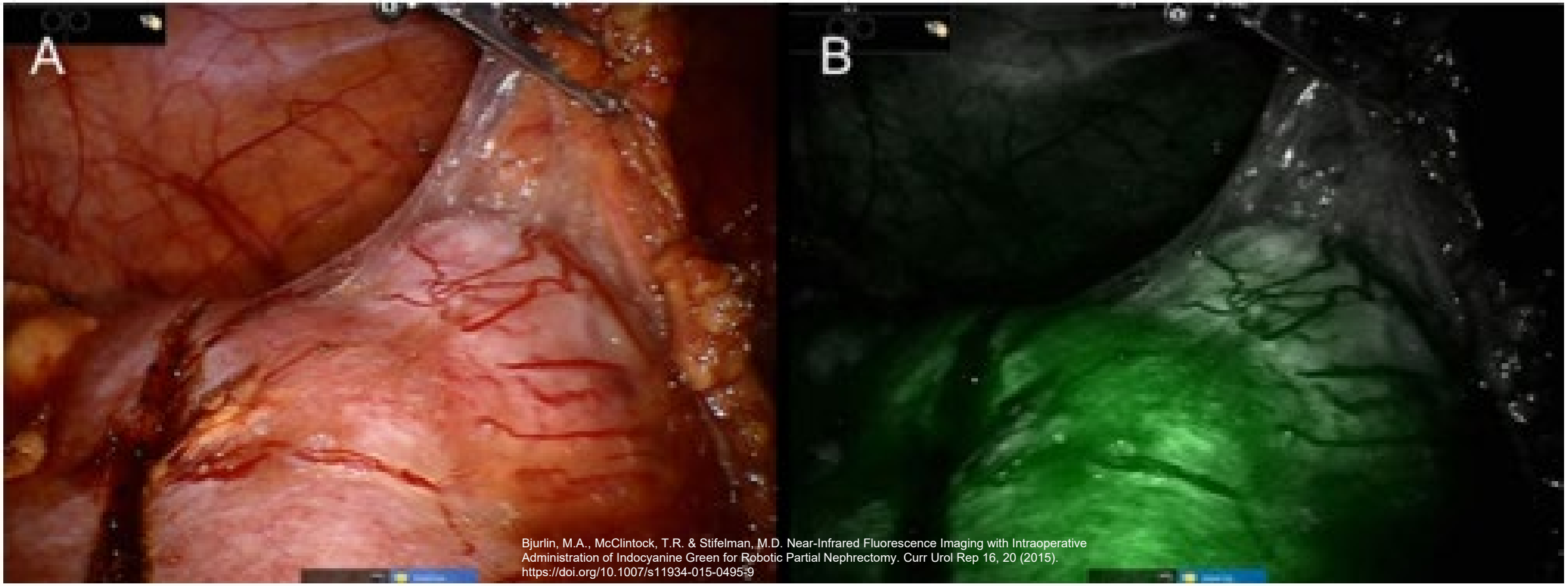
Clinical Applications continued..

- Using the same technique in 2016 *Department of Urology, New York University, Langone Medical Center* used ICG for robotic partial nephrectomy, first to potentially allow for the differentiation of renal tumor from normal parenchyma. In this application, it has been hypothesized that normal kidney tissue fluoresces green color, while the tumors commonly remain hypo-fluorescent, thereby aiding tumor excision.

- Secondly, Near-Infrared Fluorescence (***NIRF***),imaging with ICG has been employed to facilitate selective arterial clamping during robotic partial nephrectomy, allowing for a regional perfusion deficit in the kidney to be readily identified and therefore targeted at a given tumor.

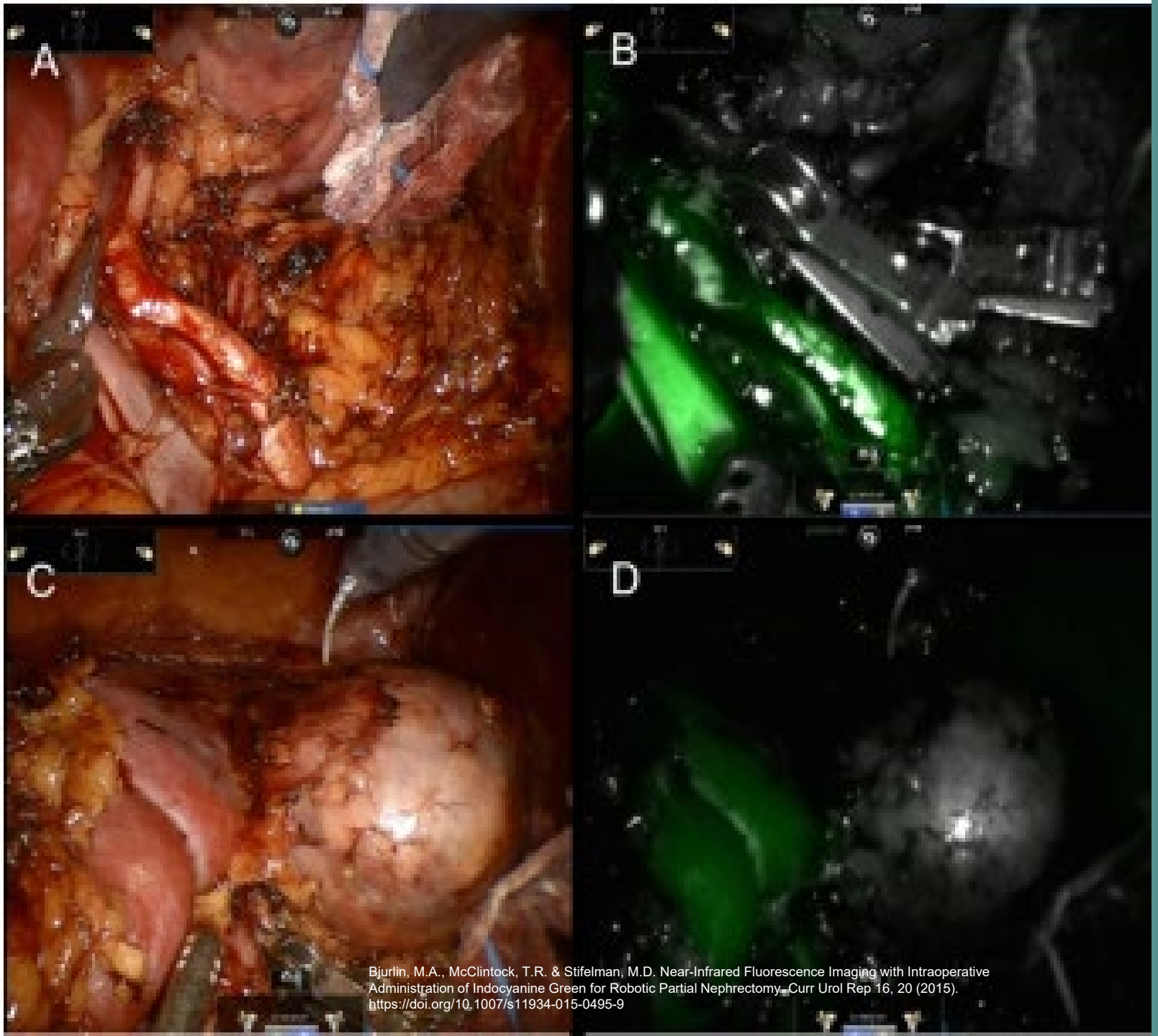
- Impact on functional outcome, that of estimated glomerular filtration rate (eGFR), through decreasing ischemia in normal tissue. NIRF imaging allows the surgeon to confirm the devascularization of a tumor and local area and continued perfusion of normal tissue. This technology provides real-time intraoperative renal angiograms to confirm selective ischemia. In this way, NIRF imaging aids in the confirmation of a bloodless field and may also offset some of the skill- and operator-dependent properties.

Images from Tumor Excision



Bjurlin, M.A., McClintock, T.R. & Stifelman, M.D. Near-Infrared Fluorescence Imaging with Intraoperative Administration of Indocyanine Green for Robotic Partial Nephrectomy. Curr Urol Rep 16, 20 (2015). https://doi.org/10.1007/s11934-015-0495-9

NIRF imaging with ICG to facilitate optimization of renal tumor localization. Renal mass seen under white light (a) and under NIRF imaging with ICG demonstrating a hypo-fluorescent tumor adjacent to bright green normal renal parenchyma (b)



Bjurlin, M.A., McClintock, T.R. & Stifelman, M.D. Near-Infrared Fluorescence Imaging with Intraoperative Administration of Indocyanine Green for Robotic Partial Nephrectomy. Curr Urol Rep 16, 20 (2015). https://doi.org/10.1007/s11934-015-0495-9

NIRF imaging with ICG to facilitate selective arterial clamping. Dissection of the secondary, tertiary, or quaternary level arterial branches (a), selective arterial clamping with mini bulldog clamps seen under NIRF imaging with ICG (bright fluorescent green vessels) (b), renal tumor seen under white light (c), and NIRF imaging with ICG (hypo-fluorescent renal tumor confirming ischemia with perfused bright green normal renal parenchyma) (d)

Outcome of the use of Fluorescence & Robotic Surgery

- **All of the other surgeries had the following the outcome:**
- **Avoided ischemia**
- **Patient's improvement in short-term follow-up.**
- **Reduced risk of recurrence and retreatment.**
- **Minimally invasive successful surgeries.**
- **High success rate in being able to avoid disruption of any other vessel or organ.**
- **Other secondary infections were avoided.**
- **Improvement to the da-vinci machine.**
- **Used to identify metastasis, with high accuracy rate.**

Current Updates

- Currently the use of ICG is still in use for a lot of the procedures that are being performed. As of right now, in terms of improvement, folic acid conjugate is being used to get better imaging sensors. The normal window for ICG in the light spectrum 600 nm –1,350 nm but with blood and water it is minimized to wavelengths of 1,000 nm. Folic acid can reach up to even further wavelengths than that of 1,350 nm as used in a ovarian cancer surgery done by the *Oncology Surgery Department in Netherlands*. ***(Center for Devices and Radiological Health)***

- Fluorophores, such as IRDye800CW are under clinical investigation in numerous tumor types, such as head and neck, pancreatic, breast, brain cancers and squamous cell carcinomas. ***(Center for Devices and Radiological Health)***

Conclusion

In conclusion, the combination of fluorescence and robotic surgery has come a long way. New findings are published in nearly all surgical specialties regarding the uses of fluorescence imaging. Great implementation is found in assessing perfusion, mapping, and visualizing anatomy. As more targeted agents progress through clinical trials and gain FDA approval, the prevalence of the fluorescence platform will increase. As a progression of time and technological advancement, the discovery of new indicator markers will come along, new procedures will use fluorescence marker, and there will be other robotic surgeries that may not even need these markers.

Bibliography

1. Van Oosterom, M., Meershoek, P., Simon, H., Mengus, L., Maurer, T., & Van Leeuwen, P. et al. (2019). First-in-human translation of a DROP-IN gamma probe – Integration of radioguidance during robot-assisted laparoscopic surgery. *European Urology Supplements*, *17*(7), e2294. doi: 10.1016/s1569-9056(18)32696-4
2. Ngô C;Cornou C;Rossi L;Bats AS;Bensaid C;Frati A;Nos C;Lécuru F;, C. (2016, September). *Evidence for the use of robotically assisted surgery in gynecologic cancers*. Current opinion in oncology. Retrieved September 12, 2021. DOI:10.1097/CCO.0000000000000315
3. DeLong, J., Hoffman, R., & Bouvet, M. (2016). Current status and future perspectives of fluorescence-guided surgery for cancer. *Expert Review Of Anticancer Therapy*, *16*(1), 71-81. doi: 10.1586/14737140.2016.1121109
4. Lee, Y., Krishnan, G., Nishio, N., Berg, N. S., Lu, G., Martin, B. A., Keulen, S., Colevas, A. D., Kapoor, S., Liu, J. T., & Rosenthal, E. L. (2020). Intraoperative Fluorescence-Guided Surgery in Head and Neck Squamous Cell Carcinoma. *The Laryngoscope*, *131*(3), 529–534. doi: 10.1002/lary.28822
5. Meershoek, P., KleinJan, G., van Willigen, D., Bauwens, K., Spa, S., & van Beurden, F. et al. (2021). Multi-wavelength fluorescence imaging with a da Vinci Firefly—a technical look behind the scenes. *Journal Of Robotic Surgery*, *15*(5), 751-760. doi: 10.1007/s11701-020-01170-8
6. Hernot, S., van Manen, L., Debie, P., Mieog, J., & Vahrmeijer, A. (2019). Latest developments in molecular tracers for fluorescence image-guided cancer surgery. *The Lancet Oncology*, *20*(7), e354-e367. doi: 10.1016/s1470-2045(19)30317-1
7. Morrell, A., Morrell, A. C., Morrell-Junior, A. C., Mendes, J. M., Tustumi, F., & Morrell, A. G. (2021). INDOCYANINE GREEN FLUORESCENCE IMAGING IN ROBOTIC SURGERY: STATE OF ART, TIPS AND TRICKS IN CURRENT APPLICATIONS. *Arquivos de gastroenterologia*, *58*(1), 61–70. doi:10.1590/S0004-2803.202100000-11
8. Pathak, Ram A., Hemal, Ashok K. (2019).Intraoperative ICG-fluorescence imaging for robotic-assisted urologic surgery: current status and review of literature. *International Urology and Nephrology*. doi:10.1007/s11255-019-02126-0.
9. KleinJan, G., van den Berg, N., Brouwer, O., de Jong, J., Acar, C., & Wit, E. et al. (2014). Optimisation of Fluorescence Guidance During Robot-assisted Laparoscopic Sentinel Node
10. Stewart, H. L., & Birch, D. J. (2021). Fluorescence guided surgery. *Methods and Applications in Fluorescence*, *9*(4), 042002
11. Desiderio, J. *et al.* (2018) "Fluorescence image-guided lymphadenectomy using Indocyanine Green and near infrared technology in robotic gastrectomy," *Chinese Journal of Cancer Research*, 30(5), pp. 568–570. Available at: https://doi.org/10.21147/j.issn.1000-9604.2018.05.11

12. Desiderio, J. *et al.* (2018) "Fluorescence image-guided lymphadenectomy using Indocyanine Green and near infrared technology in robotic gastrectomy," *Chinese Journal of Cancer Research*, 30(5), pp. 568–570. Available at: https://doi.org/10.21147/j.issn.1000-9604.2018.05.11.

Bibliography

18. Wagner, O. J., Louie, B. E., Vallières, E., Aye, R. W., & Farivar, A. S. (2012). Near-infrared fluorescence imaging can help identify the contralateral phrenic nerve during robotic thymectomy. *The Annals of thoracic surgery*, *94*(2), 622–625. https://doi.org/10.1016/j.athoracsur.2012.04.119
19. Nguyen, Q. T., Olson, E. S., Aguilera, T. A., Jiang, T., Scadeng, M., Ellies, L. G., & Tsien, R. Y. (2010). Surgery with molecular fluorescence imaging using activatable cell-penetrating peptides decreases residual cancer and improves survival. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(9), 4317–4322. https://doi.org/10.1073/pnas.0910261107
20. Spinoglio, G., Bertani, E., Borin, S., Piccioli, A., & Petz, W. (2018). *Green indocyanine fluorescence in robotic abdominal surgery. Updates in Surgery.* doi:10.1007/S13304-018-0585-6
21. Daskalaki, D., Aguilera, F., Patton, K., & Giulianotti, P. C. (2015). *Fluorescence in robotic surgery. Journal of Surgical Oncology, 112(3), 250–256.* doi:10.1002/jso.23910 10.1002/jso.23910
22. Landau, M. J., Gould, D. J., & Patel, K. M. (2016). *Advances in fluorescent-image guided surgery. Annals of Translational Medicine, 4(20),392–392.* doi:10.21037/atm.2016.10.70
23. Yu, H. Y., Friedlander, D. F., Patel, S., & Hu, J. C. (2013). The current status of robotic oncologic surgery. *CA: a cancer journal for clinicians*, *63*(1), 45-56.
24. Borofsky, M. S., Gill, I. S., Hemal, A. K., Marien, T. P., Jayaratna, I., Krane, L. S., & Stifelman, M. D. (2013). Near-infrared fluorescence imaging to facilitate super-selective arterial clamping during zero-ischaemia robotic partial nephrectomy. *BJU international*, *111*(4), 604-610.
25. Emara, A. M., Kommu, S. S., Hindley, R. G., & Barber, N. J. (2014). Robot-assisted partial nephrectomy vs laparoscopic cryoablation for the small renal mass: redefining the minimally invasive 'gold standard'. *BJU international*, *113*(1), 92–99. https://doi.org/10.1111/bju.12252
26. Bates, A. S., & Patel, V. R. (2016). Applications of indocyanine green in robotic urology. *Journal of robotic surgery*, *10*(4), 357–359. https://doi.org/10.1007/s11701-016-0641-5
27. Metildi, C. A., Kaushal, S., Snyder, C. S., Hoffman, R. M., & Bouvet, M. (2013). Fluorescence-guided surgery of human colon cancer increases complete resection resulting in cures in an orthotopic nude mouse model. *journal of surgical research*, *179*(1), 87-93.
28. Daskalaki, D., Aguilera, F., Patton, K., & Giulianotti, P. C. (2015). Fluorescence in robotic surgery. *Journal of surgical oncology*, *112*(3), 250–256. https://doi.org/10.1002/jso.23910
29. Landau, M. J., Gould, D. J., & Patel, K. M. (2016). Advances in fluorescent-image guided surgery. *Annals of translational medicine*, *4*(20), 392. https://doi.org/10.21037/atm.2016.10.70
30. Young, R., Rajkomar, A. K. S., Smart, P., & Warrier, S. K. (2020). Robotic complete mesocolic excision using indocyanine fluorescence imaging in colorectal cancer: A case study and technical approach. *International journal of surgery case reports*, *69*, 32–34. https://doi.org/10.1016/j.ijscr.2020.01.038
31. Lee, Y. J., van den Berg, N. S., Orosco, R. K., Rosenthal, E. L., & Sorger, J. M. (2021). A narrative review of fluorescence imaging in robotic-assisted surgery. *Laparoscopic surgery*, *5*, 31. https://doi.org/10.21037/ls-20-98
32. Aggokabo, O. P. (2020). Fluorescence assisted cancer surgery. *American Journal of Biomedical Science & Research*, *11*(1), 73–77. https://doi.org/10.34297/ajbsr.2020.11.001589
33. Wagner, O. J., Louie, B. E., Vallières, E., Aye, R. W., & Farivar, A. S. (2012). Near-infrared fluorescence imaging can help identify the contralateral phrenic nerve during robotic thymectomy. The Annals of thoracic surgery, 94(2), 622–625. https://doi.org/10.1016/j.athoracsur.2012.04.119
34. Spinoglio, G., Bertani, E., Borin, S., Piccioli, A., & Petz, W. (2018). Green indocyanine fluorescence in robotic abdominal surgery. Updates in Surgery. doi:10.1007/S13304-018-0585-610.1007/S13304-018-0585-6
35. Maza, G., & Sharma, A. (2020). Past, Present, and Future of Robotic Surgery. *Otolaryngologic clinics of North America*, *53*(6), 935–941.
36. DeLong, J., Hoffman, R., & Bouvet, M. (2016). Current status and future perspectives of fluorescence-guided surgery for cancer. *Expert Review Of*

Acknowledgement

Mentor:

Dr. Alexey Pryakhin MD, PhD

The Use of Fluorescence to Guide Robotic Surgery for Complete Tumor Excision

Authors: Josephine Araya, Joel Bascombe, Leopold Choi, Brian Johnson, Ragavendiran Lav, Jodie Thane
Mentors: Dr. Alexey Pryakhin

Saint James School of Medicine

Saint Vincent & The Grenadines

Introduction

Robotic surgery/robotic-assisted surgery are novel minimally invasive surgical techniques. The use of robotics began in the early 1980s with the first documented surgery using the Unimation Programmable Universal Manipulation Arm (PUMA) 200 for brain needle biopsy[1]. There have been several iterations and advancements of robotics with the modern day Da Vinci Si HD and Da Vinci Xi improving resolution, extending reach and adding the capability of fluorescent imaging[2]. Multiple arms for a laparoscopic design to conduct surgeries from different trajectories have improved intraoperative and postoperative surgical outcomes. Thus, robotically-assisted surgery overcomes the limitations of traditional laparotomies by offering a minimally invasive alternative that minimizes blood loss, dramatically reduces perioperative complications and improves post-operative recovery time[3].

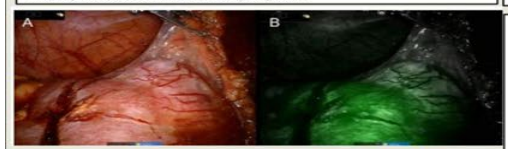
In recent years, FDA approval of robotics has expanded the applications for malignant and nonmalignant diseases. Specifically, robotic assisted surgery has been used to treat various cancers such as head and neck, breast, lung, esophageal, hepatocellular carcinoma, gastric, colorectal, anal, prostate, and penile cancers[4]. The benefits of this minimally invasive surgical technique has contributed to improved postoperative outcomes with minimal bleeding and improved recovery time[4]. However, robotic assisted tumor excision has not been without limitations. A stagnant rate of positive margins, inability to distinguish healthy and malignant cells and the dependence on the surgeon's expertise has led to poor survival and secondary malignancies[5]. Thus, although robotics has improved patient recovery time, the dependence on surgeon palpation to confirm malignant margins contributes to subjectivity and reduced sensitivity. To address this, fluorescence has been introduced to guide malignant excision using robotic surgery[6]. Fluorescence provides high single-cell sensitivity to illuminate malignant cells with low fluorescent emission of surrounding healthy tissues. The Da Vinci Si and Xi systems have been easily assimilated to incorporate fluorescence to guide robotic surgery[7]. Delong et al. demonstrated the ability of fluorescence to show high fidelity real-time tumor visualization with minimal background fluorescence. Moreover, Hernot et al. illustrated the ability of fluorescence imaging to detect tumor tissue with 91% sensitivity, 100% sensitivity for tumor-positive resection margins (<2mm), and 95% sensitivity for close resection margins (<5mm). Morrell et al. have used fluorescence to minimize intraoperative injuries with the ability to aid visualization of vasculature and anatomical structure. The ability of fluorescent dyes to selectively label malignant cells has been associated with the enhanced permeability and retention effect of highly metabolically active cancer cells [8]. Particular interest has been the use of near infrared (NIR) fluorescent probes with emission between 700-900 nm (REF). NIR fluorescent probes have shown enhanced tissue depth penetration with low autofluorescence (REF).

To date many applications of tumor excisions using NIR fluorescent probe guided robotic surgery have been documented. Pathak et al., were able to show improved overall microscopic tumor excision with minimized off target effects. Commonly used FDA approved fluorescent dyes include Isocyanine Green (ICG), Methylene Blue and Protoporphyrin IX (PpIX,,)[4,9,10,11]. These dyes have been used for their selective uptake into malignant cells with minimal fluorescence of healthy cells.

This review aims to assess the benefits of NIR fluorescent dyes in robotic assisted tumor excisions with regards to reducing the onset of secondary malignancies and improving surgical margins and intra/post-operative outcomes.

Methods

We conducted a systematic literature search through the Saint James School of Medicine Library resources and by using the PubMed and Google Scholar. Key text words for search "robotic surgery," with the use of boolean operator "AND," "Secondary malignancy," Excision," "Oncology," "cancer," "Tumor incisions," 5-Aminolevulinic acid (5-ALA)," "Protoporphyrin IV (PpIx)," "Isocyanine Green (ICG)," Methylene Blue,". Another criterion that will be used is peer-reviewed and or scholarly papers. Our systematic literature review will utilize sources through the Saint James School of Medicine library such as PubMed, EBSCO, google scholar electronic database. Inclusion criteria will be the following: 1) Papers newer than 2010 as sources, 2) Scholarly or peer-reviewed papers, 4) Use of specific fluorescent dye as well as the use of only articles that are published in the English language. Exclusion criteria will be as follows: 1) Articles that are not found within the mentioned search engine, 2) All papers that are published prior to 2010 3) Articles not using fluorescent or robotic surgery, 4) Papers not available in English language. Bias will be minimized through the use of multiple search engines and the use of selection criteria. Reduction of confounding will be mediated by conducting a literature review solely and using only the information presented through said scholarly articles. Quality of outcome will be measured in survival rate, surgical time, complications, and effectiveness in secondary malignancies.

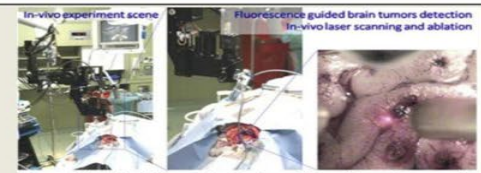


NIRF imaging with ICG to facilitate optimization of renal tumor localization. Renal mass seen under white light (a) and under NIRF imaging with ICG demonstrating a hypofluorescent tumor adjacent to bright green normal renal parenchyma (b)

Results

In the extensive literary research we have done, we have seen that in many procedures, the use of fluorescence with robotic surgery proved to improve successful rates of excisions of tumors. Such procedures seen with this include lymphadenectomy,colorectal and hepatobiliary surgery, laparoscopic adrenalectomy, laparoscopic partial nephrectomy, colon cancer oncology, colon resection, phrenic nerve thymectomy, and tumor ablation in neurosurgery. All of the surgeries showed successful excision and lowered risks due to successful outcomes of ischemia, improvement in short-term follow up, reduced risk of recurrence and retreatment, avoidance of major vessels or other organs, identification of metastasis, and avoidance of secondary infection.

However, this technology is not without its limitations. Fluorescence dyes such as ICG can only penetrate shallow depth of tissue. This low penetration ability of ICG and fluorescence dye limits its usage in surgery with inflammation, fibrosis and abundant fat tissue. Another limitation of ICG is that it has very high sensitivity, but low specificity of tissue. Because of this reason, ICG is only used to identify sentinel lymph nodes to evaluate cancer spreading. With better penetration ability of future fluorescence dyes, application of improved dye will be multiplied. Lastly, the implementation cost of the robotic assistance guiding system requires much more investment, and the cost of maintenance of this machine impacts on the cost of overall robotic assisted surgery to a patient and insurance company.



Integrated diagnosis and therapeutic system for precision malignant gliomas resection

Conclusion

From analyzing and accumulating the data from robotic general surgery with the use of fluorescent and other markers. We learned that NIF-ICG is mainly used for identification of the biliary and vascular anatomy, but its applications are rapidly expanding also in colorectal, thoracic and endocrine surgery. It is a safe, reproducible, non-invasive method that does not expose patients and personnel to radiation. Low tissue penetration is one of the major limits of ICG fluorescence. Novel systems will soon be available, overcoming this issue and improving the fluorescent signal. In the future, the development of new software will allow better processing of the images and quantification of the information. The most valuable future application of the NIF system, combined with the technological advancements in robotic technology, will be fluorescence-guided surgery. New agents, such as specific ligands and monoclonal antibodies conjugated to fluorophores could allow real time intraoperative tumor detection and even molecular diagnosis. NIF could become an optimal tool, not only for avoiding lesions to specific structures (vessels, nerves, etc.) during the surgical procedure, but also for accurate intraoperative staging, with precise lymph node detection, specific recognition of metastatic lymph nodes and differentiation between normal and neoplastic tissue, even at a microscopic level (i.e., resection margin evaluation). Future technological advancements will expand the indications of NIF-ICG. New fluorescent agents with deeper penetration to tissue, quantitative analysis of data, and real-time in vivo microscopy, in addition to a new, improved robotic platform, will allow for accurate intraoperative diagnosis and treatment. It will be a revolutionary method that will change the concept of performing surgery as we know it. Larger randomized trials are still required in order to determine the full benefit of this technique. Fluorescence imaging technology is gaining several new surgical applications. At the same time, the technology itself is frequently being updated, with many new fluorescent probes and imaging strategies in development. However, several obstacles and limitations still exist that must be overcome for fluorescent imaging to gain even wider use than its current applications. The surgical team acknowledged the utility of the technology in real time differentiation of tissues and identification of vascular structures, providing immediate guidance during surgery. NIR Fluorescence is a dynamic tool, the effects of which are improved with timely dye administration. This timing is largely reliant on the organ being operated and the astuteness of the operating team. The technology is not without its shortcomings—its role in right adrenalectomy is blunted due to hepatic fluorescence, and its suitability to adrenocortical carcinomas due to hypofluorescence of the lesion cannot be commented upon in a small series. NIR fluorescence is a safe, useful addition in laparoscopic adrenalectomy which will undergo further refinement over time. NIRF imaging with ICG also facilitates selective arterial clamping and thereby negates the need for global ischemia by allowing for real-time confirmation of targeted ischemia in the tumor while maintaining perfusion of normal tissue during robotic partial nephrectomy. Its low incidence of adverse effects and non-nephrotoxic properties.Current literature applying NIRF imaging with ICG to facilitate selective arterial clamping during robotic partial nephrectomy. BMI body mass index, EBL estimated blood loss, WIT warm ischemia time, NR not reported allow for its safe adoption. Further studies are needed to identify appropriate dosing to achieve maximal fluorescent differential between renal tumor and normal parenchyma and to determine long-term oncological and renal function outcomes. Provided essential evidence that fluorescence guided navigation provides a more effective tumor resection (large and invasive tumors) as well as increasing tumor-free survival rates. Although in this study open operation technique was used, let it be noted that it should be well suited to work with laparoscopic and robotic surgery with the extra visual help obtained from ACPPDs or the activatable cell-penetrating peptides conjugated with dendrimers. One question that remains is whether the potential benefits of fluorescent imaging warrant the cost of adding it to a surgical field.

Literature Cited