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Peroperative personalised decision support and analytics for colon cancer surgery- Short report

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ABSTRACT

Advanced instrumentation whether robotic or non-robotic- hasn't itself made for better surgery as all critical measures of operative success depend still on intraoperative surgeon judgement and decision-making. Computer assisted surgery, or digital surgery, refers to the combination of technology with real-time data during an operation and is often assumed to need new hardware platforms to become a reality. However, methods to support personalised surgical endeavour exist now and can be deployed today within standard laparoscopic paradigms. Here we describe in detail the rationale for the deployment of such assistance for surgical step-advancement in our current practice evolution from traditional proximal colon cancer resection to complete mesocolic excision focussing on personalised 3d anatomical display, intraoperative, quantificative fluorescence assessment of intracorporeal anastomoses and postoperative digital feedback to enable reflection and identify areas of technical improvement.

Surgical operations are complex. Technical practice evolves meaning that specialists need to continue to specialise throughout their career. Technology also advances and should enable new techniques. However, step-evolution after completion of formal training can be challenging for those in busy practice especially when the change requires extension into new anatomical areas and/or the deployment of new skills needing not just equipment and knowledge but judgement in exactitude of application. Traditional education and training including preceptorship segue understanding and technique basics but thereafter still remains the difficulty of conversion of concept into the daily routine and progression through competency to proficiency. Therefore, many new tools remain deployed only within the original technique paradigm providing only non-inferior outcomes [1] and new techniques may not disseminate well [2] curtailing surgery's advancement.

Peroperative Computer-Assisted Surgery (CAS) can assist established surgeons evolve their operative style even in colorectal surgery in unprivileged centres today. Indeed it needs application in the crucible of enabling specialism rather than confinement to the realm of juniors' education. True digital surgery (defined as the convergence of technology, surgical technique and real-time information) is agnostic to the access platforms and can be used within any camera-assisted approach (important as laparoscopy is and will remain for foreseeable future the main operative modality for the majority of minimal access surgeries). To mitigate expense in accumulating technologies around healthcare acts, CAS digital support should reuse data already created within the patient's care pathway and represent it in ways most relevant to the operating team with a firm basis in actual reality (rather than 'virtual' or 'augmented'). Especially when being applied for deepening specialist practice, the assistance should be intuitively understandable, readily explainable and, for now, avoid extraneous paraphernalia (e.g. headsets) allowing the surgeon to remain rooted in familiarity. Blackbox technologies will come but for now the surgeon remains fully responsible for all the decisions made and should be able to know and say why whatever was done was done.

For concept substantiation, we've sequenced, additive digital support into our local step-iteration of right colon cancer surgery (see Fig. 1). Over the past decade, it has become clear that while resection remains the best option for cure of locoregional colon cancer, its oncological outcomes are lagging behind the improvements seen in similarly staged rectal cancer. Complete Mesocolic Excision (CME) with central vascular ligation (CVL) has been

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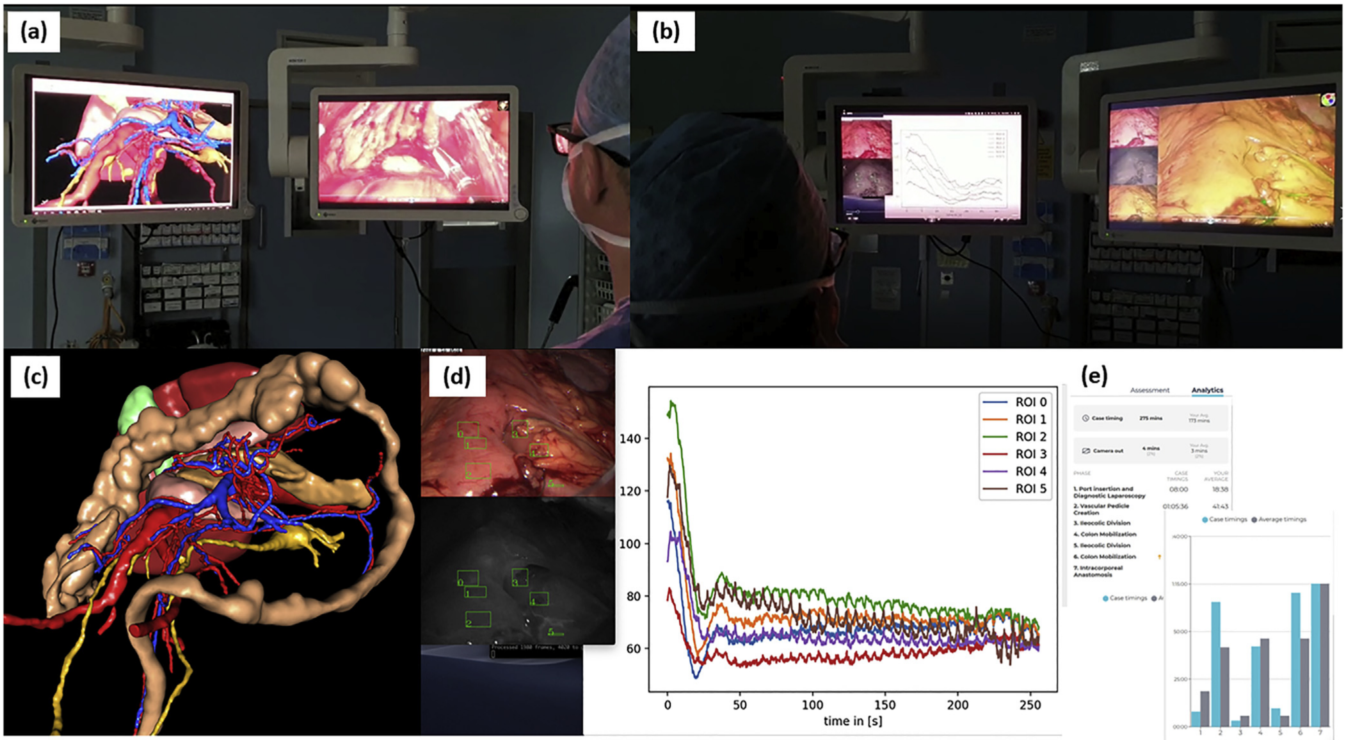

Fig. 1. In-theatre display and use of software technologies to support adoption of complete mesocolic excision with central vascular ligation for right colon cancer including intracorporeal isoperistaltic ileocolic anastomosis.
(a) Side by side display of personalised 3d model map orientated to match surgical view during central vascular ligation steps of surgery.
(b) Side by side display of fluorescence intensity graphs during near-infrared assessment of ileocolic anastomosis-shown is the initial arterial inflow peak followed by venous dissipation of signal
(c), (d) and (e) respectively screenshots from 3d anatomical map (Visiblepatient), Fluorescence intensity graphs (IBM Research in Ireland) and video analytics (Touchsurgery).

proposed as important in correcting this gap in tandem with better understanding of the distinctive biological characteristics of proximal colon cancer. At the same time increasing evidence including randomised controlled trials support the incorporation of intracorporeal anastomosis within the laparoscopic procedure to add in-hospital benefit especially with respect to postoperative ileus. Colon cancer surgery already confers specific risks of major morbidity, especially haemorrhage and anastomotic leakage, and even established surgeons worry that extending radicality and adding complexity could be dangerous most especially early in an implementation phase. This is further compounded by the fact that right colon cancer is far less common then left-sided cancer (1:3) and its treatment is dispersed through a greater number of centres limiting opportunity. To aid safe simultaneous adoption of both CME/CVL and evolution to intracorporeal anastomotic construction we've deployed the following:

(a) Personalised Mesocolic Vascular Mapping and Modelling (see Video One): Knowing probabilities is 20th century practice, the 21st century surgeon needs to know the specific anatomy of today's patient. Central D3 dissection requires CVL (high division of the relevant arteries and veins supplying the right mesocolon and colon at their junction with the superior mesenteric artery and vein) to ensure CME (more so than just correct planar surgery away from the midline vasculature). These branch vessels vary greatly between individuals in their presence and configuration (pattern of arterial/venous crossing and branch levels) [3] and inexpert address risks bleeding or subtotal mesocolic excision. While radiologists train to interpret 2d computerised tomographic slices, the images are not directly transposable to the surgical viewpoint and the written synopsis is hard to retain or refer to intra-operatively. Furthermore, while fluent throughout the coeliac plexus (the most common area of interventional angiography), the subsegmental branch pattern of the infrapancreatic superior mesenteric artery is less familiar territory. We utilise a commercial service (Visible Patient, IRCAD) that 3d reconstructs the staging CT scan within 48 h to provide a person-specific anatomical guidance model. This is cross-checked by our radiologists (developing their expertise in doing so) and viewed on a laparoscopic monitor intra-operatively with the orientation matching that of the operative view including small bowel and omental decant. Inclusion of CT angiographic phase-sequencing at staging aids millimetric resolution so the maps have greater precision then intraoperative determination (often obscured by patient adiposity or prior operation as well as surgical uncertainty). By this, the root vessels can be envisaged ahead of encounter. Furthermore, by including the inferior mesenteric arterial delta, the impact of root division of the middle colic artery by principle on distal transverse colon perfusion sufficiency can be considered. Next phase advancement includes provision with verified anatomic-sign posting (c.f. Fletcher J, unpublished data).
(b) A major barrier to the step-move from extracorporeal to intracorporeal anastomosis is uncertainty of judging vascular sufficiency visually correctly on a screen rather than being able to palpate the mesocolon and assess the cut ends externally. Especial nervousness may arise in intracorporeal reckoning following aggressive venous and arterial

dissection and transection inherent in CME/CVL. Near-infrared fluorescence angiography is now widely available and has been proven to at least match very well with surgeon judgement intra and extracorporeally and perhaps better it [4]. Alongside arterial inflow, it can also indicate venous outflow by simple continuance of viewing of the intestinal region of interest before and after anastomosis beyond a half-life clearance cycle of the circulating fluorophore ($t^{1/2} = 4$ min) alongside a relevant control loop. Quantification of signal can be provided by maintaining a set distance of visualisation and including signal intensity software graphing. This provides reassurance and document or perhaps abnormality detection that would prompt extension of the anastomotic landing zone on into an unaffected vascular territory (see Video Two).

(c) Reflective practice is a core tenet of proper professional behaviour and a cornerstone of developing technical skills. Operative video recording creates a data rich memory of the procedure providing great opportunity to hone technique and identify areas for improvement through rewatching. Contextualisation of like with like in an uncurrated video collection is difficult. Smart artificial intelligence-based automatic segmentation and chaptering of the procedure allowing easy recourse to viewing selected procedure steps in statistical comparison with other similarly categorised videos (e.g. TouchSurgery [5]) addresses this (see Video Three). Crowd-sourced interpretative analysis is another route for classification of operative steps [6]. Next phase advancement is similar computer vision application to video streams in real-time.

Adoption of surgical advances requires their broad application in the real-world. This requires their uptake and confirmation of correct deployment by surgeons widely, the majority of whom will have relatively low volume practices and/or are needed by their regions to retain unfocussed practices and in areas not readily amenable to centralisation of care. New approaches have so struggled to impact the field as adequacy of performance needs determination solely by those without the same experience. Already CAS can provide helpful oversight factoring in patient biology and heterogeneity and enabling forensic lookbacks and should be considered as a bolt-on part of the support network for practice evolution decoupling surgery from the outdated view of progress via expensive hard-wear acquisition alone. Soon machine learning will add extra value by enabling immediate contextualisation between surgeons and centres defining optimum practice and providing real-time elemental support for an era of surgical egalitarianism and equalitarianism.

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Author contributions

RC contributed the concept while RC & FK contributed manuscript design, planning, drafting, writing and final approval.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejso.2020.04.010.

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