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New insights in diagnostic laparoscopy

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Abstract: The basic concept of Diagnostic Laparoscopy (DL) is old but not old-fashioned. – Before the rise of tomography and ultrasound there was just the direct look into the abdomen and onto the affected organ available. As open surgery comes along with trauma, blood loss and infection, every effort have been made to improve the access strategies. Finally, due to innovation in optics, video technology and computer science, the look into the abdomen through a "keyhole" is a standard procedure today. – In this review we give an overview of history, implications and cost-effectiveness of DL, attempting an extrapolation of its future role.

Keywords: artificial intelligence; augmented reality; diagnostic laparoscopy; gynecology; oncology; robotics; staging laparoscopy; trauma.

Introduction

In 1945 Narancio et al. discussed *The Economic Value Of "Peritoneoscopy"* as a relatively safe minor procedure that often prevents useless celiotomies [1]. – This emphasizes the will to be as effective as open surgery with the intent to cause less damage. But is the only purpose of an laparoscopic approach to be the lesser of two evils? – Meanwhile, DL has multiple implications. In oncology, for instance, it complements the staging process for abdominal cancers. By application of *Extended Diagnostic Laparoscopy* (EDL), hidden structures like the omental bursa become accessible after dissection of anatomical barriers with minimal trauma. Nevertheless, its indication regarding particular tumor sides stays controversial. If combined with laparoscopic ultrasound (LUS) DL delivers a further gain of information defining T and N state. In 2006, Feussner et al. concluded that DL has not yet been replaced by virtual imaging as computed tomography (CT), magnetic resonance tomography (MRT) or positron emission tomography (PET). Due to the ability of real time intervention as acquisition of tissue and lavage cytology it may keep an important role in modern diagnostics [2]. More than a decade has passed since that proposition – One approach to confirm or even refute it, might be a view on the amount of scientific papers dealing with DL over the years. In *PubMed* there is a first moderate increase in the early nineties with about 500 articles per year, followed by a major increase after 2,000. The tremendous progress in techniques as well as wide spreading of laparoscopic surgery per se may be the reason. In Germany, patients that received DL between 2008 and 2018 mainly were women at an age of 20 to 60 years, according to the Destatis Genesis online database. Contrary, men of the same age underwent DL quite rarely. Even in male patients there is a peak of DL accountable in the group elder than about 40 years (Figure 1) [3]. This gender-dependendence may reflect the versatile applicability of DL in gynecology and oncology.

Material and methods

We searched for the keywords "diagnostic laparoscopy" respectively "staging laparoscopy" alone or in combination with "cancer", "trauma", "economic", "gynecology", "artificial intelligence", "robotics" and "augmented reality" in *PubMed* without limitation concerning time range of publication. We included reviews and clinical trials as well as meta-analyses to get a comprehensive overview. Furthermore, the Genesis online database by Destatis has been searched for the amount of patients that underwent a diagnostic laparoscopy (OPS code 1-694) in Germany between 2008 and 2018. The results have been sorted by age groups and sex.

Results

Visceral surgery

Staging laparoscopy has been integrated into the therapeutic decision making in abdominal cancers for many years. Thereby, the yield of diagnostic laparoscopy is

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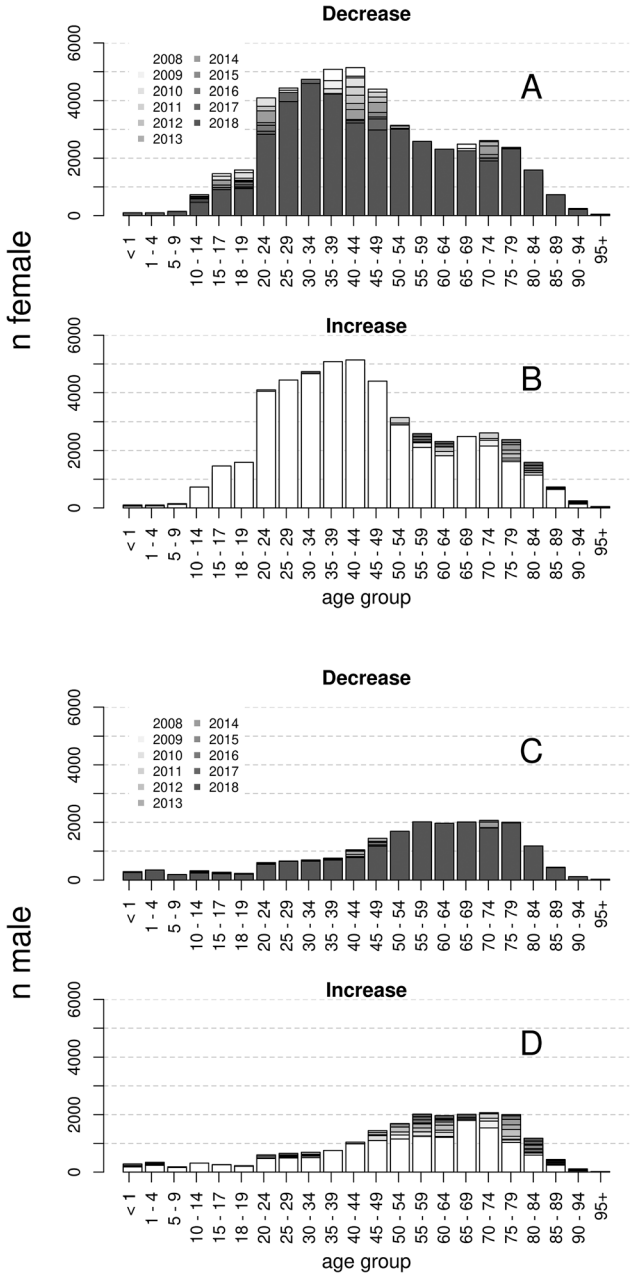

Figure 1: Frequency of diagnostic laparoscopy applied to hospital patients from 2008 to 2018 in Germany.
*Absolute frequency of DL in female (top panel) and male (bottom panel) ordered by aggregated age. **A**/**C** show an overlay of histograms for the years 2008 to 2018 with the last year on top (dark gray). A stepwise excess at the end of the bars indicates a decrease over the time period. **B**/**D** show the same years with 2008 on the top (white) and ordered inversely. Thus, an excess indicates an increase for a distinct age group. Source: Statistisches Bundesamt (Destatis) [3].*

higher in patients suffering from gastric tumors [4–6] than in cases of esophago-gastric junction cancer [7, 8] (Table 1). One reason seems to be the easy accessibility to the main part of the stomach and a disparate anatomical concept of lymphatic drain. Lymphatic vessels and nodes conducting lymph fluid off the stomach are more exposed than those of the esophagus that shares its drain system mainly with thoracic and cervical organs [9]. While DL has its place in gastric cancer it is still discussed controversial in pancreatic oncology due to the necessity of opening the omental bursa and contrary results concerning diagnostic yield. Beside medical problems, economic issues drive the controversy around DL in pancreatic cancer on. Morris et al. investigated its cost-effectiveness for this entity in Great Britain. If DL is performed to avoid meaningless open surgery it is cost-effective in about 63 % of cases, however increasing the overall costs if laparotomy is still applied subsequently [10]. Therefore, further investigation has to improve selection of patients that benefit from DL. Laparoscopic staging even can help to decide whether a neoadjuvant treatment is indicated. In borderline resectable pancreatic cancer, for instance, DL reduces the propability of surgical over-treatment if the tumor is not resectable [11, 12]. Moreover, DL prior to neoadjuvant therapy does not increase the overall costs for treatment [13]. This demonstrates that cost-effectiveness of DL depends on a certain pretest probability and thus again a reasonable selection of patient who undergo it. A recent Cochrane systemic review including 16 trials showed that, on average, DL with biopsy and histopathological confirmation of suspicious lesions can avoid 21 unnecessary laparotomies in 100 individuals, resection of pancreatic and periampullary cancer with curative intent has been planned for [14]. A great chance of improvement lies in *Artificial Intelligence (AI)*. The recognition of intraabdominal peritoneal metastases is still a problem for human surgeons as well as for computer algorithms. Schnelldorfer et al. demonstrated that surgeons misidentified about 36 % of metastases just by estimation of appearance, regarding nodularity and degree of transparency. Machine learning using a neural network did not deliver better results so far [15]. Even in primary and secondary liver malignancies DL can give a worthy contribution. Hilgard et al. showed that mini-laparoscopy contributed to the diagnosis of unknown liver diseases just by inspection of the organ surface in approximately

Table 1: Yield of staging laparoscopy in gastrointestinal malignancies, results of selected trials.

Location	Diagnostic yield
Esophago-gastric junction [7, 8]	11.1 – 11.8%
Stomach [4, 5, 6]	9.3 – 36.3%
Pancreas [11, 12]	2 – 35%
Liver [16]	23 – 33%

33 % in a cohort of 1788. In case of cancer, DL led to an upstaging in about 23 to 33 % (Table 1). On the other hand they revealed a discrepancy between macroscopic aspect and microscopic diagnosis of liver cirrhosis in about 21 %, emphasizing the imperative of sampling tissue and cytology [16].

Trauma and intensive care

DL even plays a role in trauma surgery and intensive care. During the period between 1990 and 2016 its application has declined in abdominal trauma patients. In contrast, the amount of therapeutic laparoscopies increased in these 26 years regarding trauma patients [17]. Also in penetrating abdominal trauma, DL followed by laparoscopic surgery or conversion to open surgery has been proven feasible, safe and highly accurate in identifying intra-abdominal injuries [18, 19]. In treatment of non-traumatic acute abdomen, diagnostics and curative treatment can be performed during the same session for patients suffering from appendicitis or acute cholecystitis even in pregnant women [20]. Moreover, DL in intensive care can be performed on bedside with a certain amount of preparation. Patients treated on an ICU are commonly unstable and often inappropriate for inner clinical transport. Additionally, CT scans lack on immediate intervention that goes beyond puncture of abscesses or hematomas [21, 22].

Gynecology

Another field for application of DL is gynecology, for example in detection of endometriosis lesions. Interestingly, it has a lower specificity (about 75 %) than MR, even in mild-disease. That is although DL identifies more suspect lesions generally [23]. In advanced stage ovarian cancer DL reduces the number of futile laparotomies with cytoreductive intention without increasing direct total health care costs [24]. Reversely DL can identify those women who profit from neoadjuvant treatment before debulking surgery. Van de Vrie et al. showed that in up to 60 % of patients suffering from advanced ovarian cancer, residual tumor > 1 cm is left behind after primary debulking surgery. They suppose that DL could be useful in identifying those primarily unresectable women that would gain benefit from chemotherapy before resection [25]. Unfortunately, recent studies are to various in quality and design to perform a credible meta-analysis. Even technical evolution influences DL in gynecology. Gallotta et al. compared conventional laparoscopic staging with robotic access for patients suffering from stage I ovarian cancer. They did not find a significant difference between the two groups regarding early or postoperative complications [26]. Even in staging of endometrial carcinoma robotic approach does not make a difference so far [27].

Future perspectives

As shown above, there are several developments that improve the procedure of Diagnostic Laparoscopy step by step. Beside a progress on the field of techniques and HD/4k resolution, several ongoing research projects aim for the development of supportive functionalities, which have the potential to bring DL to a new level. This includes the handling of topological changes by elastic registration [28], augmented reality [29] as well as optical tracking to improve laparoscopic skills [30]. Spectral imaging, fluorescent imaging and the application of computer vision will provide additional information beyond the bare eye view which could further augment the value of DL. Our team is engaged in some of these fields and we would like to outline our current work in AI application for DL in the talk *"COMPASS: Localization in Laparoscopic Visceral Surgery"* by Hartwig et al.

Conclusion

To understand the mechanisms of a distinct problem there is no better way than taking a "look behind the scenes". Literally, there exist few medical techniques that enable to take a "real look". Whether in gynecology, cancer or abdominal trauma, most approaches deliver a reconstruction or even withdrawal of reality. In contrast, Diagnostic Laparoscopy allows insights with an undisturbed view onto malignant tissue, bleeding and organ infraction. Furthermore, action and reaction in real time are possible. Therefore, DL doubtless has its place in modern medicine. One of its advantages is the ability to deliver histological samples which is not a domain of imaging in many situations. The combination with modern computer science alike artificial intelligence as well as improved recording of procedures and positioning will further emphasize these advantages. Already today DL should not be seen as a competing technique to other modalities. Rather, current

state of science reveals that an intelligent serial combination of several approaches delivers the best gain regarding cost-effectiveness and proper patient treatment. Nevertheless, further investigation in computer science, engineering, oncology, epidemiology, and economics is urgently needed.

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