RISK FOR THE OPERATOR RELATED TO LAPAROSCOPIC SURGERY AND SELECTED MEASURES OF THEIR MINIMIZATION

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Low invasive surgical techniques were made possible by technical progress and related miniaturization of surgical equipment. Benefits of low invasive techniques are widely known (1, 2, 3). Laparoscopy is the most common low invasive method of surgery. It became a standard management of many diseases. Other surgical techniques that became common recently include single incision laparoscopic surgery (SILS) and natural orifice transluminal endoscopic surgery (NOTES). For many years surgeons have been assisted by robots who fulfill simple tasks (e.g. keeping a camera) or even replace hands of surgeons (RAS – robotic assisted surgery).

When laparoscopy became popular, reports appeared documenting adverse effects of laparoscopic technique on doctors who used it (2). In this paper we review literature on the current state of knowledge in the area of risks related to the use of laparoscopic technique and measures of their prevention to increase the level of safety of this procedure for the patient and to avoid potentially negative effect on the health of a surgeon who performs a low invasive procedure.

Importance of awareness of risks for the surgeon during a laparoscopic procedure

Development of devices and complex tools between a patient and an operator resulted in appearance of new type of physical and mental stress related to work (4, 5). These stresses are referred to as “workload”. With regard to significant physical and mental stresses, work performed by a surgeon is compared to that of a pilot (6, 7). Due to awareness of effect of these stresses on performed tasks, they need to be minimized to provide correct course of a surgical procedure and related patient safety.

Statistical estimates indicate that 30-50% complications in surgical patients could be avoided and general level of human (patient) safety in the health care environment is several fold lowered that in the work environment with comparable risk (7, 8). Among multiple theories attempting to explain origin and correct of errors, the most commonly reported initial cause of error is a non-apparent risk related to simultaneous occurrence of a potentially dangerous situation (6). When an error do occurs, usually there is a so called “cascade of errors” and final damages depend on ability to break the chain of adverse events (9, 10). Therefore awareness of sources of potential errors reduces the chance of their occurrence and if they do occur – ability to act correctly. In view of this awareness, understanding risks related to use of laparoscopic technique provides higher level of safety of the procedure to the patient himself/herself (9, 10).

Another aspect of understanding risks for the surgeon – laparoscopist is ability to prevent phenomena resulting from excessive mental (fatigue) and physical workload at work. Workload from the first group results in erroneous decisions of the operator while from the second group – physical fatigue – results in e.g. imprecise movements. Long-term workload, persisting for months and years, results in motor system disorders related to prolonged...
maintenance of weird body positions during a surgical procedure (11).

As a whole, awareness of additional risks related to laparoscopic procedures should result in reduction of workload so as to minimize well known phenomenon of decreased efficiency (increased number of errors) at increasing physical and/or mental workload.

Ergonomics is a branch of science that deals with theoretical side of these issues. The term “ergonomics” was used for the first time in 1857 by a widely accepted creator of ergonomics, a Pole – Wojciech Bogumił Jastrzębowski who originated this name from Greek (ergon = work, nomoz = rule) and defined it as a “science dealing with work – i.e. about using strength and skills provided to a human by the Creator” (12).

There are many obstacles to using ergonomics in surgery despite vast amount of knowledge available on risk factors of operator related errors. The main cause of this phenomenon is that the science requires adjustment of work to a human, while in medicine it is impossible due to multiple considerations (i.e. specific shape of human body / surgical field as a work place, impossible change of an operator following a “recommended” time of work, etc.) (13).

Physical workload during laparoscopic procedure

Physical workload includes processes related to physical exertion and its effect mainly on the motor system. The most common direct causes of excessive and atypical (physical) workload experienced by an operator during a laparoscopic procedure include (13):

1) restriction of operator’s moves – standard, unbroken surgical tools penetrating through the skin, has 4 degrees of freedom;
2) requirement to use excessive force – up to 6-fold higher versus open surgical procedures due to worse mechanical force transmission of the tool itself and due to characteristics of release of force in a hand. In particular weakening of “closing” force of the hand occurs with flexion and ulnar deflection of the wrist (e.g. with angular shafts);
3) requirement for extensive movements (“rowing”) – related to penetration of laparoscopic tools through body walls;
4) lack of adjustment of surgical tools – one size, non-ergonomic handles (sharp edges, often non-intuitive locking mechanisms);
5) non-adjusted work place – often: one monitor on a mobile column near the operating table – position of the monitor cannot be regulated;
6) monotonous movements – most of the movements with tools involve preparation, most often using a thumb (tools with active tips) or whole upper extremity (hook);
7) forced positions with predominance of static positions – as compared to open surgical procedures, laparoscopic procedures require visual fixation on an immobile monitor and, irrespective of head/neck position – stiffening and abduction of arms with hand and wrist mobility (this position is referred to as a „chicken-wing position”). Often it is difficult to control electrosurgical tools with a pedal – European statistics indicate that more than 90% of physicians would prefer another method of triggering diathermy and 3/4 of physicians erroneously select a pedal to trigger appropriate device setting (14).

Ergonomics helps to determine causal relation between the above mentioned factors and musculoskeletal complaints that exist or will exist unless the nature of work is changed.

From the point of ergonomics, view these risks are classified to one of several groups of ergonomic risk factors, i.e. factors that induce MSDs („musculoskeletal disorders”)

Some diseases included in the MSD category are also listed by Polish law regulating work performance (i.e. such that result from a particular method of performance of a given task, e.g. laparoscopic procedure). These include e.g. chronic tendonitis, bursitis, chronic periartthritis or humeral epicondylitis.

Table 1 presents risk to the particular body segments related to a workplace or used tools. It must be emphasized that a high percentage of these factors could be avoided with a simple measures (e.g. change of monitor, column position, height of the operating table, pedal, etc.). The biggest load on the operator body during

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1 This is a collective term including particular diseases of the motor system. These conditions are universally preceded by symptoms – i.e. complaints reported by the employee himself/herself and are not confirmed by a physical examination (e.g. numbness, tingling, etc.) and confirmed by physical examination (e.g. reduced grip strength, reduced mobility, etc.)

2 Ergonomic term.
laparoscopic procedures is placed on the vertebral column (cervical and lumbar segment) and upper extremity, in particular shoulder girdle, wrist and hand. Load includes not only awkward postures but also static positions that are somewhat natural manner of keeping balance by a human (unsteady balance).

These data were obtained using results of measurements of load placed on muscle groups (most often using EMG) and subjective surveys (16, 17).

Specifics of surgical training and practice requires acceptance of experienced complaints. This problem is known worldwide. Studies of complaints experienced during surgical procedures, basing on individual questionnaires, conducted among physicians performing laparoscopic procedures (not only surgeons) showed that such complaints were present in nearly of 80% study subjects (18).

Mental stress during laparoscopic procedures

There are the following sources of mental stress during laparoscopic procedures (13):

1) Inversion of movements on a monitor relative to body movements, in a vertical and horizontal plane, so called “lever effect” – as a detrimental effect on eye-hand correlation decreases with increased experience of an operator.

2) Discrepancy between an axis of vision and a working axis of upper extremities – it has been shown when best work parameters are achieved when an axis of vision is compatible with a working axis⁴, and additional factors that need to be considered here include:

- observed working angle of the tools (tasks are performed within the shortest time when these angles are identical)
- an angle between a camera (visual axis) and working plane of the tools – optimal 0-15 degrees

3) indirect vision – an image from laparoscopic camera is:

- two-dimensional – the most evident aspect of two dimensional vision is loss of depth; adequate level of training allows the brain to estimate indirectly the depth, e.g. due to mechanical contact with a tissue, estimation of size and perspective of adjacent structures as well as basing on light reflection and shadows
- magnification (2-4x) and limitation (60-90 degrees) of the operative field
- rotation versus the operative fields – along with its increase, irrespective of the degree of experience of the operator, number of errors or decrease of precision occurs and time required to perform them increases.
- duration of laparoscopic procedures – development of laparoscopic procedures makes the procedures more and more complex.

Increased cumulative physical and mental workload during a laparoscopic procedure leads to so called “surgical fatigue syndrome” that manifested as “mental exhaustion, excess-

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³ or similar

⁴ Due to the nature of laparoscopic technique, this is essentially impossible to achieve
sive irritation, reduced ability for intraoperative assessment and reduced manual skills” (1).

Simple solutions reducing workload during laparoscopic procedures

Current study results indicate that surgeons’ awareness of ergonomics is limited although surveys among done surgeons indicate that they highly rate their own knowledge of ergonomics. Good example of this discrepancy was illustrated by a study of ergonomics of laparoscopic tools: handle A was rated very high before a subject became acquainted with a handle B; this situation was reversed when a prototype handle B was presented – then handle A was rated markedly lower (17). Quality of commonly used surgical tools made surgeons get used to it which makes new solution difficult to gain recognition. New constructive solutions may be also difficult to accept in particular by operators who have gained experience in using existing equipment, adapted for the purpose of laparoscopic techniques from classic surgery that became almost unchanged until nowadays.

It must be emphasized that the isolated fact of better ergonomics of a tool or its easier use under experimental conditions (e.g. simulator) cannot be a sole indicator determining selection of equipment to the procedure since mental stress related to its use could adversely affect general level of safety of the surgical procedure.

There are many results of studies concerning any aspect of surgeon’s work during a laparoscopic procedure (20, 21). These resulted in preparation of recommendations concerning mainly item placement at the work place. These recommendations are aimed at minimizing workload:

1. Recommendations for the image:
   1) optimal height of monitor placement is approximately 10 cm below Frankfurt horizontal plane (FHP) of an operator; this position is a compromise between an optimal plane for correct precision work and plane neutral for the motor system (in the neck);

2) distance between an operator and the image should not be lower than 0.9 m and for 14” monitors should not exceed 3.0 m; such distances enable correct determination of anatomical details;

3) the monitor should be placed before the operator – therefore the monitor should be equipped with an arm, even if it is placed on a laparoscopic column;

4) if possible, assistant should have his/her own monitor.

2. Panels of control devices (diathermy, insufflations) should be in the visual field of an operator.

3. Table should be adjusted to the elbow height of an operator – this parameter it set intuitively in most cases.

4. Method of use and localization of pedal should be considered (loss of contact with pedal keys results in concern in more than half of the operators) – permanent location, inactivation of one key when we use only one of modes of diathermia.

5. Surgical tools – if possible, tools used to hold the tissues should have locks and adequate jaw parameters to prevent tissue slipping from the tools and use of excessive force.

6. If possible, operating rooms specially designed for laparoscopic procedures should be used.

Ergonomic solutions are eagerly introduced in many work places because their benefits are obvious. Their use on the ground of surgical technique is still not very popular. This is mainly due to low ergonomic awareness of the surgeons, variable settings and level of education of laparoscopic surgeons. As far as any chance to reduce the risk of error by the operator during the laparoscopic procedure is worth exploration, the most clear benefits (i.e. surgical method that is not detrimental for the surgeon’s own health) from these recommendations will mainly be found by laparoscopic surgeons.

In the era when quality of life is much appreciated, laparoscopic surgeons should be interested in ergonomic solutions to protect their own health and patient safety during laparoscopic procedures.

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5 This is the plane established when right and left poria and left orbitale are in the same horizontal plane (Latin planum horizontale frankfurtensis)

6 This is the height between the floor and olecranon with the upper extremity flexed at the right angle.
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