Conventional laparoscopic instruments are not ergonomic and are restricted to 4 degrees of freedom (compared to 36 in open surgery). This results in severe limitations in performing simple, let alone complex tasks in surgery, holding many surgeons back from engaging in a variety of minimally invasive manoeuvres and procedures. Until recently there were only two categories of laparoscopic instruments: conventional straight manual instruments and a large, console-based, robotic system. Those surgical robotic systems offer increased dexterity, articulation and 3D vision, but at substantial financial costs and logistic complexity, as has been summarized by Perez and Schweitzberg last year (1).

Even though in a recent study (2) a robotized device did not show superiority compared to conventional laparoscopic instruments in a non-clinical setting, the development of non-robotic and therefore low-cost laparoscopic instruments that enable better dexterity has recently taken off. Anderson et al. reviewed a multitude of mechanical articulating hand-held laparoscopic devices (3). Current articulated mechanical surgical instruments exhibit a wide range of user interfaces, wrist mechanisms and capacities, however, currently there is no clear consensus on what makes an articulated mechanical instrument easy to use. Some articulated mechanical instruments have reached the commercial market and others are under development. As articulated mechanical surgical instruments mature, they have the potential to impact the minimally invasive surgery market by providing some of the capabilities currently only found in robotic systems at a lower cost.

Outside the scope of that review are dexterous
instruments that are partially motorized. A number of handheld, partially motorized/robotized devices for laparoscopic surgery have been developed, providing additional flexibility in transmitting movement from the user interface to the instrument wrist. These devices however require motors and software, placing them at some cost disadvantage compared to fully mechanical instruments. In Table 1, a summary of all available mechanical and robotized laparoscopic instruments can be found. In this short review we will focus on the robotized instruments, as there are the JAiMY®, the DEX™ Robot and the HandX™, in addition to the most widely available mechanical instrument, the FlexDex®.

The FlexDex® is based on a simple and mechanical design, translating the movements of the forearm, wrist and fingers to the tip of the instrument without electrical components (3,4). It provides articulated control and successfully enables suturing in limited spaces. The tool frame is attached as a forearm brace, thus changing instruments may be challenging and time consuming (5-7).

In New Horizons in Laparoscopic Surgery (2018), a chapter was dedicated to handheld devices (12). Of all the devices that were described to be still in the prototype phase, only the HandX™ by Human Xtensions from Israel, has been officially launched since. The device received FDA clearance and CE mark. The smart, robotized surgical system integrates all the components required for a modular

<table>
<thead>
<tr>
<th>Device</th>
<th>Type</th>
<th>Instrument</th>
<th>DOF</th>
<th>Market availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>FlexDex®</td>
<td>Mechanical</td>
<td>Needleholder</td>
<td>6</td>
<td>Worldwide</td>
</tr>
<tr>
<td>SILS® Hand</td>
<td>Mechanical</td>
<td>Interchangeable</td>
<td>7</td>
<td>Worldwide</td>
</tr>
<tr>
<td>r2 CURVE</td>
<td>Mechanical</td>
<td>Interchangeable</td>
<td>7</td>
<td>Available, mostly Europe</td>
</tr>
<tr>
<td>r2 DRIVE</td>
<td>Mechanical</td>
<td>Interchangeable</td>
<td>7</td>
<td>Available, mostly Europe</td>
</tr>
<tr>
<td>JAiMY®</td>
<td>Robotized</td>
<td>Multifunctional</td>
<td>6</td>
<td>Available, mostly Europe</td>
</tr>
<tr>
<td>DEX™ Robot</td>
<td>Robotized</td>
<td>Interchangeable</td>
<td>7</td>
<td>Available, mostly Europe</td>
</tr>
<tr>
<td>HandX™</td>
<td>Robotized</td>
<td>Interchangeable</td>
<td>7</td>
<td>Available, mostly Europe</td>
</tr>
<tr>
<td>Autonomy LaparoAngle®</td>
<td>Mechanical</td>
<td>Needleholder</td>
<td>7</td>
<td>Not available</td>
</tr>
<tr>
<td>Reallhand®</td>
<td>Mechanical</td>
<td>Interchangeable</td>
<td>7</td>
<td>Not available</td>
</tr>
<tr>
<td>Kymerax®</td>
<td>Robotized</td>
<td>Interchangeable</td>
<td>5</td>
<td>Not available</td>
</tr>
</tbody>
</table>

DOF, degrees of freedom.
platform, of which HandX is the first launched and FDA cleared. It is currently distributed in Europe by Aesculap AG, a subsidiary of B. Braun.

HandX™ (Figure 1) is designed as a light-weight, hand-held device that translates natural unrestricted hand motions into complex movements inside the patient during laparoscopy. The instrument is composed of a sophisticated user interface and a novel, motor driven articulating tool that is controlled by the interface. These components are reusable. The shaft and instrument at the tip are single-patient use and currently a needle holder and grasper are available, although most laparoscopic instruments will be launched soon. The system doesn’t require any set up time, and can be easily moved between commercially available laparoscopic 5-mm trocars. Since it was clinically launched over 200 procedures have been performed with the use of this novel device, in multiple countries in Europe as well as in the United States and Israel. The operations included upper gastrointestinal (GI) procedures (sleeve gastrectomies, paraesophageal hernia repairs, gastric bypasses), inguinal and ventral hernia repairs, cholecystectomies, hysterectomies, colectomies, solid organ procedures, thoracic procedures and prostatectomy for benign and malignant disease. The device enabled complex motions and tissue manipulation as well as suturing in difficult angles and in narrow, hard to access spaces. Several clinical trials are now underway to study the use of the device in different settings, and the cost-effectiveness profile of its use.

In conclusion, there are ongoing, interesting and promising developments of smart devices in the area of minimal invasive surgery as an alternative to the currently available robotic systems that are very complicated and costly. In addition, telemanipulated surgical systems lack haptic feedback during the surgical performance, which hand-held devices do provide. Finally, most new motorized instruments are reusable, and the cost-profile of this robot-like dexterity is therefore low. Considering the fact that many of those devices are still in early stages of development, the future for the use of those innovative solutions looks bright.

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**Footnote**

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