Increased intraperitoneal pressure up to 15 mm Hg does not reliably induce haemodynamic changes in pigs

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Summary
Haemodynamic alterations occur consistently with laparoscopic surgery in humans. These haemodynamic changes have never been reproduced in an animal model without additional potentiating factors. As these alterations may be deleterious in some patients and as the cause is only partly understood, we have used an animal model to study these changes. Pneumoperitoneum with intraperitoneal pressures of up to 15 mm Hg were produced in pigs, in the same way as for laparoscopic surgery in humans. Arterial pressure, cardiac output, pulmonary arterial pressure and systemic arterial resistance were assessed at baseline and after pneumoperitoneum had been produced. Intraperitoneal pressures of up to 15 mm Hg were not associated with consistent circulatory changes and we conclude that haemodynamic changes associated with laparoscopic surgery are dependent on species. (Br. J. Anaesth. 1997; 78: 576–578).

Key words
Carbon dioxide, pneumoperitoneum. Surgery, laparoscopy. Cardiovascular system, effects. Pig. Model, pig.

Materials and methods
After obtaining approval from the Institutional Animal Care Committee, two adult domestic pigs (mean weight 40 (SD 0.5) kg) and six piglets (18.1 (1.9) kg) were anaesthetized with ketamine i.m. and continuous infusion of fentanyl and pancuronium, and their lungs ventilated mechanically (Cicero mechanical ventilator, Dräger SA, France) with 50% nitrous oxide in oxygen after tracheal intubation. Tidal volume was set at 10 ml kg⁻¹. Ventilatory frequency was adjusted to maintain end-tidal carbon dioxide partial pressure (P\text{\textsubscript{ET}} CO\textsubscript{2}) at 4.5±0.3 kPa. Lactated Ringer’s solution was infused at 500 ml h⁻¹. The carotid artery was cannulated for monitoring systemic arterial pressure (AP) and for blood sampling. The right external jugular vein was cannulated with a 7-French pulmonary artery thermodilution catheter. Pulmonary arterial pressure (PAP), pulmonary capillary wedge pressure (PCW) and cardiac output (CO) were measured (Marquette electronics, France). SVR (dyn s⁻¹ cm⁻⁵) was calculated using the standard formula. Peritoneal insufflation with carbon dioxide was performed slowly up to 15 mm Hg, at a rate of 250 ml min⁻¹, via a Palmer needle placed percutaneously into the abdominal cavity with an insufflator allowing continuous monitoring of IPP (Laparoflator FM, Wiest KG, Germany). Haemodynamic measurements were obtained after a 15-min period of stabilization: at baseline after induction of anaesthesia and at an insufflation level of 15 mm Hg. Body temperature was maintained at 36°C.

Mean values were analysed using a paired Student’s t test. Significance was set at P<0.05.

Results
Intraperitoneal insufflation was not associated with any significant changes in either AP (P=0.59), CO (P=0.62) or SVR (P=0.63) (table 1).

Discussion
PAP and PCW increased as a consequence of increased intrathoracic pressure associated with establishment of pneumoperitoneum. However, our study failed to reproduce those changes usually observed in humans (i.e. increase in AP and SVR;
Table 1  Haemodynamic effects of increased intra-abdominal pressure. AP 1 = Systolic arterial pressure before IAP increase; AP 2 = systolic arterial pressure for IAP increased to 15 mm Hg; SVR 1 = systemic vascular resistance before IAP increase; SVR 2 = systemic vascular resistance for IAP increased to 15 mm Hg; CO 1 = cardiac output before IAP increase; CO 2 = cardiac output for IAP increased to 15 mm Hg; PCW 1 = pulmonary capillary wedge pressure before IAP increase; PCV 2 = pulmonary capillary wedge pressure for IAP increased to 15 mm Hg; P CO 2 = end tidal PCO 2 for IAP increased to 15 mm Hg. P = (1) before IAP increase, or (2) for IAP increased to 15 mm Hg.

<table>
<thead>
<tr>
<th></th>
<th>AP 1 (mm Hg)</th>
<th>AP 2 (mm Hg)</th>
<th>SVR 1 (dyn s⁻¹ cm⁻²)</th>
<th>SVR 2 (dyn s⁻¹ cm⁻²)</th>
<th>CO 1 (litre min⁻¹)</th>
<th>CO 2 (litre min⁻¹)</th>
<th>PA 1 (mm Hg)</th>
<th>PA 2 (mm Hg)</th>
<th>PCW 1 (mm Hg)</th>
<th>PCW 2 (mm Hg)</th>
<th>P CO 2 (kPa)</th>
</tr>
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<tbody>
<tr>
<td>Adult pig 1</td>
<td>92</td>
<td>97</td>
<td>1837</td>
<td>2012</td>
<td>3.7</td>
<td>3.3</td>
<td>18</td>
<td>21</td>
<td>12</td>
<td>18</td>
<td>4.8</td>
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<tr>
<td>Adult pig 2</td>
<td>84</td>
<td>89</td>
<td>2608</td>
<td>2336</td>
<td>2.3</td>
<td>2.5</td>
<td>17</td>
<td>20</td>
<td>9</td>
<td>13</td>
<td>5.2</td>
</tr>
<tr>
<td>Piglet 1</td>
<td>79</td>
<td>84</td>
<td>2933</td>
<td>2400</td>
<td>2.1</td>
<td>2.7</td>
<td>14</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td>5.3</td>
</tr>
<tr>
<td>Piglet 2</td>
<td>113</td>
<td>127</td>
<td>2971</td>
<td>1962</td>
<td>2.8</td>
<td>3.1</td>
<td>19</td>
<td>23</td>
<td>12</td>
<td>9</td>
<td>5.1</td>
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<tr>
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<td>116</td>
<td>100</td>
<td>3418</td>
<td>3672</td>
<td>2.1</td>
<td>2.2</td>
<td>17</td>
<td>27</td>
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<td>106</td>
<td>3266</td>
<td>2800</td>
<td>2.4</td>
<td>2.5</td>
<td>17</td>
<td>28</td>
<td>6</td>
<td>14</td>
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<tr>
<td>Piglet 5</td>
<td>76</td>
<td>71</td>
<td>3341</td>
<td>3200</td>
<td>2.7</td>
<td>2.7</td>
<td>16</td>
<td>18</td>
<td>12</td>
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<tr>
<td>Piglet 6</td>
<td>74</td>
<td>80</td>
<td>2061</td>
<td>2545</td>
<td>2.6</td>
<td>2.2</td>
<td>13</td>
<td>14</td>
<td>5</td>
<td>5</td>
<td>5.1</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>92 (17)</td>
<td>97 (17)</td>
<td>2804 (5910)</td>
<td>2741 (532)</td>
<td>2.6 (0.5)</td>
<td>2.7 (0.3)</td>
<td>16.4 (1.9)</td>
<td>20.3 (5.7)</td>
<td>9.1 (3.6)</td>
<td>12.1 (5.7)</td>
<td>5.1 (0.2)</td>
</tr>
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</table>

P 0.59 0.63 0.62 0.03 0.07

It is questionable if the drugs given to our pigs may have affected the data. Ketamine stimulates the sympathetic system causing increases in AP and SVR. As increases in AP and SVR were the main haemodynamic changes expected, and as no increases in AP or SVR occurred even in the presence of possible co-existing sympathetic stimulation induced by ketamine, we conclude that ketamine had no effect. Fentanyl stimulates the parasympathetic system, therefore fentanyl may have impaired the expected haemodynamic changes. However, continuous infusion of fentanyl has been shown to cause minimal haemodynamic changes and is unlikely to have completely masked the anticipated findings. Pancuronium produces tachycardia via parasympathetic block. However, this effect is weak and is unlikely to have impaired the expected haemodynamic effects of increased IPP. We did not study IPP at values greater than 15 mm Hg, but several studies using higher IPP (up to 40 mm Hg) failed to reliably reproduce haemodynamic changes associated with pneumoperitoneum in humans.

In our investigation, peritoneal insufflation and pressure control were assessed with an insufflator validated for this use. Haemodynamic assessment with a thermodilution pulmonary artery catheter is a routine and reliable technique in animal and human investigations. Body temperature and PCO 2 were maintained within the physiological range and fluid status was monitored closely. Our sample size may have been too small to draw definitive conclusions, but no consistent trend occurred in haemodynamic changes. In accordance with previous studies, inclusion of two adult pigs in the study suggests that maturity is not a major factor.

In summary, we believe that our study, in accordance with previous similar studies, provides the following information: (a) haemodynamic changes associated with laparoscopic surgery in humans cannot reliably be reproduced in a pig model; (b) haemodynamic disturbances associated with IPP are dependent on species; (c) extrapolation to humans of data recorded in animal models during laparoscopic procedures must be made with caution.

References

The pig model was chosen as this animal is related to humans, both physiologically and anatomically. Its cardiovascular system is similar with respect to the size and distribution of coronary vessels, arterial pressure, heart rate, cardiac index, regional distribution of carbon monoxide and maximum oxygen consumption. However, examination of many studies conducted in animals to reproduce haemodynamic disturbances associated with increased IPP, shows discrepancies between studies for every level of IPP and even for baseline measurements. Moreover, haemodynamic changes similar to those in humans during laparoscopic surgery have never been reproduced in animals without additional potentiating factors: IPP increased to more than 20 mm Hg and in some studies up to 40 mm Hg; hypovolaemia or a vasodilating agent, or both; hypercapnia or acidosis; and coexisting thoracic incision for haemodynamic investigation. In published studies, IPP has been increased by various physical methods: carbon dioxide or nitrogen insufflation, external counterpressure of the abdominal wall, intraperitoneal fluid infusion and intra-abdominal implantation of an inflatable bag. Indeed, regional differences in abdominal pressure have been described when IPP is increased by methods other than intraperitoneal gas or liquid insufflation. Moreover, a vascular reflex might have been elicited in some procedures by compression or distension of intraperitoneal viscera. Only two animal species, dogs and pigs, have been assessed and in almost all studies, animals have been anaesthetized with either pentobarbitone or fentanyl, both of which are unlikely to upset haemodynamic changes observed in humans during laparoscopic procedures.


