Blood pressures and penile muscle activity in the stallion during coitus

S. D. BECKETT, R. S. HUDSON, D. F. WALKER, T. M. REYNOLDS, AND R. I. VACHON
School of Veterinary Medicine and Department of Mechanical Engineering, Auburn University, Auburn, Alabama 36830

Blood pressure and penile muscle activity in the stallion during coitus. Am. J. Physiol. 225(5): 1072-1075. 1973.—Electromyographic (EMG) electrodes were implanted in the ischiocavernous (IC) and bulbocavernous (BC) muscles of the Shetland stallion to monitor muscle activity. A needle-tipped polyvinyl catheter or subminiature pressure transducer was implanted in the corpus cavernosum penis (CCP) to determine the pressure during coitus. Results from the needle-tipped catheter show that the mean CCP pressure during the quiescent state of the penis was 13 mm Hg, increasing to 107 mm Hg when a receptive mare was brought into view. During coitus, mean peak CCP pressure was 3,998 mm Hg. Higher mean peak CCP pressures were recorded from the subminiature transducers with a mean of 6,530 mm Hg. The lower peak CCP pressures obtained from the catheter were because of the viscous forces associated with the small diameter of the catheter, and the elasticity of the polyvinyl dampened the frequency response so that the maximum peak pressure was not recorded. Correlation of the EMG activity with the peak CCP pressures indicates that the IC muscles were the source of energy for the extremely high pressures. This was further substantiated by the fact that anesthesia of the IC muscles with lidocaine greatly reduced the CCP pressures of the stallions during attempted coitus.

The level of CCP pressure during erection was reported by Henderson and Roepke (8) as approximately equal to carotid pressure. However, this pressure was recorded in anesthetized dogs with erection produced by electrical stimulation of the nerves to the penis. Lewis et al. (10) in a preliminary paper reported that the CCP pressure in the bull during coitus was 1,727 mm Hg. Recently, Beckett et al. (2) reported that the mean peak CCP pressure in the goat during coitus was 7,003 mm Hg.

The electromyographic (EMG) activity of the external penile muscles has been investigated in the dog during coitus by Hart (6). He suggested that the IC muscles do not have an important role in facilitating erection. Hart and Kitchell (7) stimulated various areas of the penis in spinal and intact dogs and reported that the EMG patterns of the bulbocavernous (BC) muscles were consistent with the accepted concept that rhythmic contraction of these muscles aided in the forceful expulsion of seminal fluid and in pumping blood from the proximal expansion of the corpus cavernosum urethra (CCU) into distal parts of the CCU.

The activity of some striated muscles associated with ejaculation has been studied in man using EMG techniques (9, 12). There was reduced EMG activity of several muscles of the urogenital diaphragm some seconds before ejaculation with an increase in the activity during orgasm. However, it is not known how the activity was distributed in all of the different muscles during the process of ejaculation. It was concluded that the striated urethral sphincter (i.e., BC muscle) underwent rhythmic contraction serving to express the semen.

The purpose of this study was to determine the pressure in the CCP of the stallion during coitus, to compare the CCP pressure with mean arterial pressure, and to determine the source of energy for the CCP pressure.

**MATERIALS AND METHODS**

Healthy, sexually mature Shetland stallions were studied during copulation following surgical implantation of recording instrument terminals. With each stallion under halothane anaesthesia and in dorsal recumbency, the base of the penis and IC and BC muscles were exposed by midline perineal incision. For measurement of CCP pressure, two techniques were used: 1) a needle-tipped polyvinyl catheter or 2) a subminiature pressure transducer was implanted in the CCP 4 cm distal to the insertion of the IC muscles. Paired silver ring electrodes were placed in the IC and BC muscles. The transducer cable or polyvinyl catheter and...
plastic-coated EMG lead wires were routed subcutaneously and exteriorized near the base of the tail in the left gluteal region. The placement of the subminiature transducer and EMG electrodes is shown in Fig. 1. A catheter was also surgically implanted in the carotid artery of the stallions equipped with subminiature pressure transducers by the method of Buck et al. (3). The catheters were filled with heparinized saline and flushed twice weekly. After a recovery period of 2 weeks, the stallions were bred to a receptive mare maintained in estrus with weekly injections of diethylstilbestrol. During coitus, four parameters were monitored: 1) CCP pressure, 2) carotid artery pressure, 3) EMGs of IC, and 4) BC muscles. The recording system consisted of a multichannel oscillographic recorder. The transducer for measuring CCP pressure via the polyvinyl catheter was a specially designed pressure transducer (MS-10, Microdot Inc., City of Industry, Calif.) with a range of 0–250 psi (0–12,500 mm Hg). The implanted subminiature pressure transducers (P-12, Konigsberg Instruments, Pasadena, Calif.) also had the same range. The transducers were calibrated from 0 to 200 psi (0–10,000 mm Hg) in 50-psi increments with a dead-weight tester (1 psi = 51.7 mm Hg). The calibration of the transducer attached to the catheter was checked before and after each breeding. The subminiature transducers were calibrated before implantation and recalibrated immediately after removal from the stallion at the end of the experiment. CCP pressures exerted on the subminiature transducer and the EMG activity of the muscles were recorded by telemetry (Bio-Sentry Telemetry, Inc., Gardena, Calif.)

Data were collected from three stallions using needle-tipped catheters and from six stallions with subminiature transducers implanted in the CCP.

After four normal recordings were obtained on each stallion, the IC muscles were anesthetized by local infiltration of 2% lidocaine 20 min prior to coitus. This procedure was used to determine if the high CCP pressure would be abolished when the muscles were anesthetized. Two additional recordings of coitus were obtained 24 hr or more after lidocaine injection to ascertain that the CCP pressures returned to preanesthesia levels.

Table 1. CCP pressures associated with coitus in the stallion using a polyvinyl catheter

<table>
<thead>
<tr>
<th>Factor</th>
<th>n</th>
<th>CCP Pressure, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9</td>
<td>13 ± 1.5</td>
</tr>
<tr>
<td>Precoitus</td>
<td>9</td>
<td>107* ± 8.4</td>
</tr>
<tr>
<td>Coitus</td>
<td>15</td>
<td>4,147* ± 142.0</td>
</tr>
<tr>
<td>Postcoitus</td>
<td>9</td>
<td>86* ± 23.0</td>
</tr>
</tbody>
</table>

Values are means ± se. * Significantly different from control at <0.01 level.

Results

Table 1 shows the results using the needle-tipped polyvinyl catheter in the CCP. The mean CCP pressure during the quiescent state of the penis was 13 mm Hg. When a receptive mare was brought into view, the CCP pressure rose to 107 mm Hg and pulsed at the same frequency as the arterial pressure. As the mare was brought into position and the stallion became more excited sexually, the CCP pressure increased significantly above the systemic blood pressure. After intromission, the CCP pressure occurred as peak pressures in phase with the electrical activity of the IC muscles as shown in Fig. 2. The mean peak pressure of 15 determinations with catheters was 4,147 mm Hg. Peak CCP pressure was the highest CCP pressure recorded during coitus. The highest and lowest peak pressures were 4,911 and 3,150 mm Hg, respectively. Within 1 min after ejaculation and when the stallion had dismounted, the CCP pressure had decreased to 86 mm Hg.

In the stallions in which the subminiature transducers were implanted, the absolute zero could not be checked because the entire transducer was within the CCP. However, when the penis was in a quiescent state, a relative zero could be obtained, which was adequate for measuring the peak CCP pressures. The mean peak pressure of 70 determinations was 6,530 mm Hg (Table 2). The peak CCP pressures varied between breedings of the same stallion as well as among stallions. The highest and lowest peak CCP pressure recorded during coitus were 10,340 and 3,722 mm Hg, respectively.
The average duration of coitus, as measured from the sudden increase in CCP pressure until it returned to a level approximately equal to carotid pressure, was 34 sec.

Anesthesia of the IC muscles with lidocaine reduced the mean peak CCP pressure to 1,422 mm Hg during attempted coitus. The lowest and highest peak CCP pressures of the six stallions in which the IC muscles were anesthetized were 517 and 3,878 mm Hg, respectively; however, there was still some IC muscle contraction as evidenced by EMG activity. The stallions with the low pressures could not copulate because of insufficient erection for intromission.

**DISCUSSION**

The increase in the CCP pressure from 13 mm Hg during quiescence to 107 mm Hg during mild erection was due to vasoconstriction of the arterial blood supply and of the vascular structure within the CCP. This is supported by the facts that 1) the CCP pressure during mild erection pulsed at the same frequency as the carotid artery and 2) there was a lack of EMG activity of the IC and BC muscles during this period. Similar results for the goat were reported by Beckett et al. (1, 2). Also Christensen (4) reported a pressure increase in the dorsal artery of the penis of the dog during erection. In addition, Henderson and Roepeke (8) reported that the CCP pressure in anesthetized dogs increased to a level just below carotid pressure, an average duration of coitus, as measured from the sudden increase in CCP pressure until it returned to a level approximately equal to carotid pressure, was 34 sec.

Anesthesia of the IC muscles with lidocaine reduced the mean peak CCP pressure to 1,422 mm Hg during attempted coitus. The lowest and highest peak CCP pressures of the six stallions in which the IC muscles were anesthetized were 517 and 3,878 mm Hg, respectively; however, there was still some IC muscle contraction as evidenced by EMG activity. The stallions with the low pressures could not copulate because of insufficient erection for intromission.

There was a difference in the peak CCP pressures recorded by way of the polyvinyl catheter and the subminiature transducers. However, there was overlap in the range of pressure recorded by the two methods. The pressures recorded with the catheter were lower because: 1) viscous forces associated with the small diameter of the catheter tended to dominate inertial forces associated with rapid fluctuations experienced at the peak pressures, and 2) the elasticity of the polyvinyl dampened the frequency response so that maximum peak pressures were not recorded. Also the sponge-like nature of the CCP tissue limited the volume of blood delivered to the catheter during the short time intervals of the peak pressures. On the other hand, the entire subminiature transducer was placed within the CCP so that volume displacement and dampening effects were eliminated or greatly reduced. This resulted in recording of higher peak pressures with the subminiature transducer which should be more representative of the actual pressure present.

The possibility of artifact in the recording of pressures by transducers is considered to be unlikely due to the soft and cavernous nature of the tissue of the CCP in which the transducers were deeply placed. The catheter method completely removed the possibility of artifact from point forces, and while the catheter readings were in general lower than those recorded by transducers, there was overlap in the results of the two methods.

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**TABLE 2. Carotid and CCP pressures associated with coitus in the stallion**

<table>
<thead>
<tr>
<th>Stallion</th>
<th>n</th>
<th>Peak CCP Pressure, mm Hg</th>
<th>Control</th>
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<th>Postcoitus</th>
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<td></td>
<td></td>
<td></td>
<td>Sys</td>
<td>Dia</td>
<td>Mean</td>
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<tr>
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<td>89</td>
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<tr>
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<td>6,294</td>
<td>121</td>
<td>69</td>
<td>86</td>
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<td>12</td>
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<td>7,067</td>
<td>110</td>
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<td>80</td>
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<td>9,296</td>
<td>121</td>
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<tr>
<td>Mean</td>
<td></td>
<td>6,530</td>
<td>120</td>
<td>71</td>
<td>87</td>
</tr>
<tr>
<td>se</td>
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<td>±2.4</td>
<td>±2.6</td>
<td>±2.6</td>
<td>±2.4</td>
</tr>
</tbody>
</table>

Pressure were recorded by subminiature transducer implanted in corpus cavernosum penis. *Significantly different from control at <0.01 level.
REFERENCES


