Effects of staple size, tissue thickness, and precompression time on staple shape in side-to-side jejunocecal anastomosis in specimens obtained from healthy horses at an abattoir

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Objective—To determine effects of staple size, precompression time, and tissue thickness on staple shape and tissue approximation in side-to-side jejunocecal anastomosis in equine specimens.
Sample—Cecum, ileum, and jejunum specimens obtained from 18 healthy horses at an abattoir.
Procedures—Specimens were allotted into 2 groups. Anastomoses were stapled with 4.8- or 3.8-mm staples. Precompression time was 15 seconds for both groups. Staple lines were cut into proximal, middle, and distal sections. Thickness of intestinal walls was measured with a calibrated tissue micrometer, photographs were obtained, and intestinal tissues were digested. An investigator measured staples and assessed the shape of staples on high-definition digital images. Number of optimally shaped staples and staple height were compared among sections and between groups.
Results—Use of 4.8-mm staples resulted in poor approximation of tissues in the distal sections of anastomoses. The percentage of optimally shaped staples was 538 of 551 (97.6%) and 616 of 634 (97.2%) for 4.8- and 3.8-mm staples, respectively. The percentage of optimally shaped staples did not differ significantly between groups for the same sections. There was a lower percentage of optimally shaped staples in the distal sections than in the proximal and middle sections of each group. Mean staple height did not differ significantly among sections of each group.
Conclusions and Clinical Relevance—Use of 3.8-mm staples with an adequate precompression time for jejunocecal anastomosis in horses resulted in proper staple shape. These findings could be used to improve the technique and outcome for stapled jejunocecal anastomoses in horses. (Am J Vet Res 2014;75:680–684)
ommended, without consideration of tissue health and thickness. However, to our knowledge, there have been no reports defining guidelines for the stapling technique or assessing the optimal size of staples to use for jejunoocecal anastomosis in horses.

The objective of the study reported here was to evaluate the effect of precompression time, staple size, and tissue thickness on staple shape and tissue approximation in intestinal tissues obtained from healthy horses. We hypothesized that 3.8-mm staples could achieve an optimal shape and height with good tissue approximation in an in vitro assessment of stapled side-to-side jejunoocecal anastomoses in horses.

**Materials and Methods**

**Sample**—Intestinal specimens comprising the cecum, ileum, and 3 m of jejunum were collected from 18 horses immediately after the horses were killed at an abattoir. Horses ranged from 18 to 30 months of age (mean, 24 months), with a body weight of 300 to 500 kg (mean, 400 kg).

**Procedures**—A random-number generator was used to assign specimens to each of 2 groups. Staples were used to create 80-mm-long side-to-side jejunoocecal anastomoses. Anastomoses were performed in 9 intestinal segments by use of a linear cutting staplera loaded with 4.8-mm staples. Identical anastomoses were performed in 9 other intestinal segments by use of the same stapling devicea loaded with 3.8-mm staples. Anastomoses were performed in accordance with a technique described elsewhere. Briefly, the transected end of the jejunum (ie, jejunal stump) was closed with a Parker-Kerr suture pattern and apposed with 2 stay sutures to the wall of the cecum at a point between the dorsal and medial tenia. Two 1-cm-long enterotomies were performed to allow insertion of the stapler’s jaws into the intestinal lumens. Once the stapler was positioned, it was held closed for 15 seconds (precompression time) before insertion of the staples, as previously described. Enterotomies were then closed with 2-0 polyglactin 910b in a Cushing pattern.

**Macroscopic appearance**—Intestinal segments were connected to a manometer and inflated to a pressure of 8 mm Hg by means of a compressor that provided 1 L of air/min. This pressure was chosen because a preliminary study conducted by our laboratory group revealed it resulted in the best possible shape of the anastomosis without causing stretching or disruption. Photographs of the staple lines for gross anatomic comparisons were obtained with a digital camera.

**Intestinal wall thickness**—Each staple line was divided into three 2.5-cm sections (proximal, middle, and distal). Intestines were incised longitudinally at a point on the lumen opposite the anastomosis. Each author separately measured the wall thickness of the jejunum and cecum 3 times in the center of each section. Measurements were obtained by use of a calibrated tissue micrometer at a location adjacent to the anastomosis. The tissue micrometer was set at a pressure of 8 N/m², which is the pressure reported for use with surgical stapling devices.

**Tissue digestion and analysis of staples**—Sections of each staple line were identified and placed separately in a digestion solution of 20% NaOH in distilled water; sections were incubated at 40°C for 72 hours. After intestinal tissues were completely digested, the staples were cleaned in distilled water, dried, and stored in plastic tubes. Subsequently, each set of staples was aligned on graph paper, and high-definition digital images were obtained for analysis. Each digital image was imported into imaging software for measurement analysis. The image scale was recalibrated for each staple. An investigator (GG) who was not aware of the tissue source of the staples characterized the shape macroscopically as optimal (B, R, or D shape) or suboptimal (C, X, or U shape). Optimal was defined as closed staple tips, and suboptimal was defined as open staple tips. That same investigator measured the maximal height of each staple; only optimally shaped staples were used for height measurements.

**Statistical analysis**—Mean tissue thickness was compared between groups by use of an unpaired t test with Welch correction. The number of optimally shaped staples was determined. The percentage of optimally shaped staples in each group was expressed as an overall percentage. Percentages were compared between groups with the Fisher exact test. The number of optimally shaped staples in each section (proximal, middle, and distal) for each group was determined and expressed as a percentage. Percentages for each section were compared between groups and among sections within each group by use of the Fisher exact test. Mean height of optimally shaped staples was evaluated among sections (proximal, middle, and distal) of each group with a 1-way ANOVA.

All analyses were performed by use of commercially available statistical software. For all tests, values were considered significant at P < 0.05.

**Results**

**Intestinal specimens**—There were no episodes of device malfunction during the study. One anastomosis performed with 4.8-mm staples was discarded because of technical error at the time of tissue harvest; thus, 17 jejunoocecal anastomoses were used for evaluation. Broken or damaged staples were excluded from the analysis. During division of the staple lines, 161 of 1,346 (12.0%) staples were broken or damaged; thus, only 1,185 (88.0%) staples were analyzed.

**Macroscopic appearance**—Macroscopically, the use of 4.8-mm staples resulted in poor apposition of tissues in the distal section of the anastomoses, which was evident as wide spaces between the tissue edges (Figure 1). This was considered poor placement of staples. By contrast, there was much better tissue apposition with the 3.8-mm staples.

**Intestinal wall thickness**—Mean tissue thickness did not differ significantly between the 2 groups (Table 1). Mean ± SD combined wall thickness of the jejunum and cecum walls was 3.43 ± 0.48 mm for the 4.8-mm group and 3.41 ± 0.30 mm for the 3.8-mm group.
Analysis of staples—The overall percentage of optimally shaped staples exceeded 97% in both groups and was not significantly different between groups. Percentages of optimally shaped staples for the same sections did not differ significantly between the 2 groups.

However, within each group, there was a significantly lower percentage of optimally shaped staples in the distal section, compared with the percentage of optimally shaped staples in the proximal and middle sections (Table 2).

Mean height for optimally shaped staples did not differ significantly among the 3 sections within each group (Table 2). However, mean height for optimally shaped staples differed significantly between the 2 groups.

Discussion

The study reported here was conducted to compare the effectiveness of staples of different size for jejunocecal anastomosis in horses. We focused on staple shape, which is essential to yield an anastomosis that does not leak, and staple height, which is essential for preservation of tissue integrity and hemostasis.

Macroscopically, 4.8-mm staples resulted in a loose apposition of tissue on the distal section of the anastomosis, whereas the 3.8-mm staples more closely apposed the tissues (Figure 1). This loose apposition for the 4.8-mm staples could lead to anastomotic leakage or hemorrhage.3 We did not detect leakage of air from inflated anastomoses, although evaluation of leakage was not a purpose of this study. Intestinal wall thickness is used to determine the appropriate staple size and influences proper staple shape once a staple is inserted. In the present study, the mean combined thickness of the jejunal and cecal walls was > 3.4 mm and exceeded the recommended thickness for use of both staples (2 and 1.5 mm for 4.8-mm and 3.8-mm staples, respectively). The percentages of optimally shaped staples did not differ for the same sections between the 2 groups, which indicated that tissue thickness was not excessive for either group. For moderately edematous tissue, use of precompression would allow formation of an optimal staple shape, although the use of staplers on edematous or thickened intestinal tissues is typically contraindicated.

Staple shape was considered optimal or suboptimal on the basis of whether the tips of a staple were closed or open, respectively.3 Proper apposition of tissue is not achieved if the tips of a staple are open.2,3 The percentage of optimally shaped staples in the distal section of the staple line was significantly lower than that in the proximal and middle sections in both groups. This difference may have been attributable to cartridge-to-anvil deflection, misalignment, or improper advancement of the stapler handle. This fact was confirmed by the macroscopic appearance of the distal section of the sta-

![Figure 1—Photographs of the distal section of a representative staple line for a jejunocecal side-to-side anastomosis performed with 4.8-mm staples (A) or 3.8-mm staples (B) in specimens obtained from a healthy horse at an abattoir. Distal is to the left, and proximal is to the right. Notice that several 4.8-mm staples are not optimally shaped and there is a large space between the tips of the staples that could lead to improper hemostasis. By contrast, the 3.8-mm staples provide better tissue apposition](image-url)

<table>
<thead>
<tr>
<th>Table 1—Intestinal tissue thickness (mm) for jejunocecal side-to-side anastomoses performed with 2 sizes of staples in specimens obtained from 18 healthy horses at an abattoir.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>4.8 mm (n = 8)‡</td>
</tr>
</tbody>
</table>

Values reported are mean ± SD; thickness was measured by use of a micrometer with pressure set at 8 N/m². *Size of staples. †Combined thickness of jejunum and cecum. ‡One anastomosis in this group was discarded because of technical error at the time of tissue harvest.

<table>
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<tr>
<th>Table 2—Number and percentage of optimally and suboptimally shaped staples for each section and each group for jejunocecal side-to-side anastomoses performed with 2 sizes of staples in specimens obtained from 18 healthy horses at an abattoir.</th>
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<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>4.8 mm (n = 8)‡</td>
</tr>
<tr>
<td>3.8 mm (n = 9)</td>
</tr>
</tbody>
</table>

Optimal was defined as closed staple tips, and suboptimal was defined as open staple tips. *One anastomosis in this group was discarded because of technical error at the time of tissue harvest. **Within a row, values with different superscript letters differ significantly (P < 0.05).

See Table 1 for remainder of key.
mended in human surgery.2–5,13 Ever, the use of precompression is commonly recom-
duced in stapled anastomoses of horses. How-
the size of the horse or thickness of the tissues.
size of the 4.8-mm staples was lower
had been advocated in horses,8–10 without regard for the
inappropriate tissue apposition.
the resulting height for the 4.8-mm staples was lower
manufacturer's specifications3 for the 3.8-mm staples, where-
as the resulting height for the 4.8-mm staples was lower
(1.69 ± 0.07). This finding may have resulted from thin tis-
resulted in optimal staple shapes. Nevertheless, we cannot exclude the possibility that
inconsistent and differ among surgeons, even among
the use of only larger (4.8 mm) staples
Correct use of a stapling device is essential.3 How-
ning the size of the staples. As an alternative, state-of-the-
the study reported here was the first in
One limitation of the present study, which was
patient line and is in accordance with results of another
We did not detect a significant difference in the
percentage of optimally shaped staples between the 2
groups. This indicated similar behavior for staples of
both sizes in the intestinal specimens of the present
study.
Resulting staple height corresponded to the manu-
facturer's specifications3 for the 3.8-mm staples, where-
as the resulting height for the 4.8-mm staples was lower
than expected1 (manufacturer's specifications, approx
2 mm). This finding may have resulted from thin tis-
DVeVe-De-De-

e 4.8-mm group.
See Table 1 for remainder of key.

<table>
<thead>
<tr>
<th>Group</th>
<th>Proximal</th>
<th>Middle</th>
<th>Distal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8 mm (n = 8)</td>
<td>1.73 ± 0.07</td>
<td>1.69 ± 0.07</td>
<td>1.75 ± 0.12</td>
<td>1.73 ± 0.08</td>
</tr>
<tr>
<td>3.8 mm (n = 9)</td>
<td>1.46 ± 0.065</td>
<td>1.45 ± 0.108</td>
<td>1.50 ± 0.056</td>
<td>1.47 ± 0.085</td>
</tr>
</tbody>
</table>

Values reported are the mean ± SD; only optimally shaped sta-
ples were measured. This represents the mean value for the 3 sections. Within a col-
umn, value differs significantly (P < 0.05) from the value for the
4.8-mm group.

Table 3—Staple height (mm) for each 2.5-cm section of jejunoce-
cal side-to-side anastomoses performed with 2 sizes of staples in
specimens obtained from 18 healthy horses at an abattoir.

of the biphasic behavior of intestinal tissue, there is a
noticeable change in tissue thickness during the first
15 to 20 seconds of precompression, which then plate-
teau.2 Precompression prepares the tissue for staple
insertion, reduces stress on the tissue prior to staple
insertion, minimizes tissue blood flow, and helps to
avoid serosal tears.2 Thus, precompression might be
useful when performing surgery on healthy or
edematous tissue by causing expulsion of excessive
fluid from the tissue and diminishing tissue thick-
ness.2 In the present study, a precompression time of
15 seconds was sufficient to allow a high percent-
age of optimally shaped staples in both groups, de-
spite the fact that the combined tissue thickness ex-
cceeded the manufacturers' recommendations. To our
knowledge, the study reported here was the first in
which a precompression time of at least 15 seconds,
followed by insertion of 3.8-mm staples, was used
for jejunocecal anastomoses in specimens obtained
from horses and resulted in optimal staple shapes.
Nevertheless, we cannot exclude the possibility that
shorter precompression times could also result in
optimal staple shapes in horses. Further evaluation
of the use of 3.8-mm staples without application of
precompression would be warranted. Use of 3.8-mm
staples without application of precompression has
been evaluated in other species.2–5,13

It is desirable to select a cartridge on the basis of
wall thickness of the intestines and to use an adequate
precompression time, which could easily be accom-
plished in open abdominal surgeries by measuring intes-
tinal wall thickness with a micrometer before choos-
ing the size of the staples. As an alternative, state-of-the-
art staplers, such as linear cutting staplers with select-
able staple size,4,6 are commercially available, although
one of these staplers6 is currently available only for
endoscopic surgical procedures. These staplers, along
with the appropriate staples, could be used to improve
tissue apposition and hemostasis in many situations
without changing the staple cartridge.

Although further in vivo studies are needed, we
concluded that when performing jejunocecal anasto-
mosis in horses with 4.8-mm staples, surgeons must
take particular care to examine for leakage or hemor-
hage after completion of an anastomosis, as suggested
by the guidelines for stapled side-to-side anastomosis
in humans.1,14 Equine surgeons should be aware that
methods and technologies are available to improve the
performance of stapled side-to-side jejunocecal anas-
tomoses. Surgeons are advised to choose staples of an
appropriate size and to apply precompression before
insertion of staples to potentially reduce complications
related to use of these techniques.

a. Autosuture GIA Multifire 80, Covidien Italia, Segrate, Italy.
b. Vicryl, Ethicon, Johnson and Johnson Italia, Milan, Italy.
c. Micrometer Mitutoyo M110-25, Mitutoyo Italiana srl, Lainate (MI), Italy.
d. ImageJ, National Institutes of Health, Bethesda, Md.
e. GraphPad InStat, version 3.5 for Windows, GraphPad Software Inc, San Diego, Calif.
f. Ethicon NTLC linear cutting stapler, Johnson and Johnson Italia, Milan, Italy.
g. Autosuture Tri-staple, Covidien Italia, Segrate, Milan, Italy.

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References


