The Mechanism of the Delay in Gastric Emptying Time Caused by Anoxemia*

By

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I

N previous communications (1), (2), we have re-
ported that anoxemia causes a delay in the evacua-
tion of the stomach. Although marked individual var-
iations in the response of different animals to anox-
emia were observed, most animals manifested some
delay at 560 mm. of pressure and only one out of 29
dogs failed to show delay at 450 mm. of pressure. The
findings naturally raised the question of the mechan-
ism of the delay.

It seemed logical to start the investigation for
answering this question by determining the effect of
anoxemia on the pyloric sphincter. Also, since the
vagi are predominantly concerned with the motor
mechanism of the sphincter we directed our attention
to these nerves. Further, vasospasm from anoxemia
has been demonstrated by Eyster and Meek (3),
Greene and Gilbert (4), Van Liere and Crisler (5) and
others. All of this work was focused on the relation
of the vagus to the heart under anoxemia, though
Greene (6), suggested that the effect might be ex-
pected in its relation to the gut. We, therefore, orig-
inally suggested that anoxemia causes a vasospasm
which leads to a pylorospasm which in turn is the
actual cause of the slowed emptying. In some “acute”
experiments performed in the meantime (7), we found
that anoxemia, produced by 10 per cent oxygen or less
in the inspired air of anesthetized dogs, invariably
caused a fall in tone and a decrease in the amplitude
of contractions of the filled stomach. The data in this
paper show that the effect of anoxemia on the empty-
ing of the stomach may be divided, depending upon the
severity of the anoxemia, into those attributable to the
pylorospasm, as we suggested, and into those attribut-
able to a decreased motility of the stomach.

METHOD

Normal and control anoxic gastric emptying times
were established in 14 dogs. The diet and experimental
procedure were those reported in our former paper (2).
The degrees of anoxemia used were 760, 560, 450 and 360
mm. of pressure corresponding respectively with 20.96,
15.45, 12.75 and 9.94 per cent oxygen and to 0; 8,200;
13,750 and 19,265 feet in altitude. The animals were then subjected
to various operative and experimental conditions and cor-
responding emptying times were determined. Throughout
this paper we have called the emptying time at 760 mm.
before operation, “the normal emptying time”, and after
the various operations, “the postoperative normal”. Some
animals were used for more than one procedure so that
more than fourteen individual series of experiments were
performed. In nine animals the pyloric sphincter effect-
ively was obliterated, as checked at autopsy, by pyloro-
plasty (Rammstedt’s operation). In two of four dogs the
pyloric outlet was supplemented by a posterior gastro-
enterostomy and in the other two it was excluded, the
pylorus being ligated at the time of the performance of the
gastro-enterostomy. In four animals 11100 gr. of atropine
was given just before each test in the experimental series
at various degrees of anoxemia. In one animal the vagus
fibers to the pylorus were sectioned by making a circular
incision around the stomach down to the mucosa about 1
cm. proximal to the pyloric orifice, the muscular layers
being held together by four anchor stitches which served
to prevent undue retraction of the cut structures. While
this procedure probably does not deprive the more distal
portion of the pylorus, including the sphincter, of all of
its parasympathetic innervation, it does interrupt most of
the fibers and the results were clear enough that we may
assume we were dealing with complete parasympathetic
denervation.

RESULTS

The animals in the present series make the individ-
ual variations in the normal emptying times between
different animals more apparent than ever, so that in
most of the tables we have expressed the effect in
terms of 100 per cent for the normal emptying time
and for the postoperative normal. This serves to make
the variations of different animals apparent only
under experimental anoxic conditions while the var-
iations in the normal emptying times before and after
experimental operative procedures are concealed. The
numbers in the tables represent the average of a num-
ber of tests in each case. Because we determined the
emptying times to a + or −15 minutes only, the ac-
curacy of our tables is within about 8 per cent; hence,
a change of less than this amount is insignificant
unless all values vary in the same direction.

Effects of operative procedures per se. In Fig. 1
the results of a typical animal in each group are shown
in hours. It will be noted that after the various opera-
tions the stomach usually emptied slightly more slowly than normally at 760 mm. The animals were studied long enough after operation to rule out the effects of postoperative convalescence. These results will be dealt with at length in another paper.

Pyloroplasty. After pyloroplasty and under anoxemia the stomach did not empty more slowly than the postoperative normal until a stage of anoxemia well below that causing slower emptying before operation was reached. In fact, after the operation at 560 mm. the stomach emptied faster than normally at 560 mm. before operation. At 450 mm. the stomach emptied distinctly faster than normal before operation, while it emptied in the postoperative normal time after operation. At 360 mm. more marked slowing occurred before than after operation. After completion of the data on this animal, as a check on the efficacy of the denervation, the peripheral end of the vagus was stimulated under ether. The typical pylorospasm did not occur and at autopsy scar tissue forming a bridge across the suture line was found, but time had not been allowed for any functional vagus regeneration. These results are summarized in Table 1D.

DISCUSSION

We now have a series of 29 dogs all of whose stomachs emptied more slowly during anoxemia, confirming our previous report on 6 animals. We never have had a dog whose stomach failed to show the delay at some stage of anoxemia. The threshold for the delay in most animals lies around a pressure of 560 mm. (15 per cent oxygen), though three animals showed faster emptying at this grade of anoxemia. If vagospasm is the mechanism involved in the delay, one might reason that the motor effect of the vagus on the stomach in these exceptional cases is prepotent over its motor effect on the pylorus.

The removal of the pylorus by operative section left the emptying time of the stomach dependent upon its own motility, there being no impediment to the outgoing food. In this instance reducing the pressure to 450 mm. (12.75 per cent oxygen) usually did not delay evacuation. When the pylorus was replaced or supplemented by gastro-enterostomy the same effects obtained. These results indicate that in the less severe grades of anoxemia the stomach empties slower because of pylorospasm, for it empties slower before pyloroplasty and gastro-enterostomy but in the postoperative normal time afterwards. It should be recognized that the threshold values for anoxemia vary with different animals so that it is possible for one animal to give the same sort of response at 450 mm. pressure as another would at 450 mm. because of the spasm. When pressures below 450 mm. are used then the stomach empties slower, partially or entirely, depending upon whether the pylorus is functional or not, because of decreased stomach motility.

TABLE I.

Selected representative animals showing emptying times at various grades of anoxemia, A. before and after pyloroplasty in terms of per cent of normal, B. before and after gastro-enterostomy, C. before and after 1/100 gr. of atropine in hours and D. before and after parasympathetic denervation of the pylorus in hours and in terms of per cent of normal. In dogs B II and B III the pylorus was also ligated at the time of operation.

<table>
<thead>
<tr>
<th>Dog No.</th>
<th>760 mm. pr.</th>
<th>560 mm. pr.</th>
<th>450 mm. pr.</th>
<th>580 mm. pr.</th>
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<tbody>
<tr>
<td></td>
<td>20.96 % 62.</td>
<td>15.45 % 62.</td>
<td>12.75 % 62.</td>
<td>9.94 % 62.</td>
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<tr>
<td></td>
<td>0 ft. alt.</td>
<td>8.20 ft.</td>
<td>13.75 ft.</td>
<td>19.25 ft.</td>
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<td>Before</td>
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<td>%</td>
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<tr>
<td>After</td>
<td>%</td>
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A. Pyloroplasty

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<th>100</th>
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<th>88</th>
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<tbody>
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<td>% 100</td>
<td>% 123</td>
<td>% 88</td>
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<td>174</td>
<td>125</td>
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<td></td>
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B. Gastro-enterostomy

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<thead>
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<tr>
<td>Hrs.</td>
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<td>207</td>
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<td></td>
<td>233</td>
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C. Atropine

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<th>100</th>
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<th>94</th>
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<td>Hrs.</td>
<td>% 100</td>
<td>% 100</td>
<td>% 117</td>
<td>% 94</td>
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<td></td>
<td>331</td>
<td>147</td>
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D. Parasympathetic denervation of pylorus

<table>
<thead>
<tr>
<th>I</th>
<th>6.65</th>
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<th>6.54</th>
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<tbody>
<tr>
<td>Hrs.</td>
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<td>% 9.00</td>
<td>% 6.35</td>
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VI      | 100        | 100        | 100        | 99         |
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