Effect of Thyroid Status and Thiocyanate on Absorption and Excretion of Iodine by Cattle

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Abstract

Effects of thyroidectomy or iodine-131, thyroprotein feeding, and thiocyanate dosing on radioiodine metabolism in the bovine were studied in 34 animals. Two thyroidectomized calves excreted 44% more radioiodine in urine and 38% less in feces than two thyroid-intact calves. Oral thiocyanate increased urinary radioiodine 32% in thyroidectomized and 46% in intact calves while reducing fecal radioiodine 48% in thyroidectomized and 11% in intact calves. Urinary radioiodine clearance of two heifers was increased 52% by thiocyanate, but urine flow was not affected. Percentages of radioiodine doses cycled through the abomasum daily and recovered from digestive tracts at slaughter, respectively, were: 12 thyroid-intact cows, 468 and 77; two intact cows fed 10 g sodium thiocyanate daily, 64 and 41; 10 thyroid-damaged cows, 506 and 149; and four thyroid-damaged cows fed 8 g thyroprotein daily, 372 and 93. Thyroid damage had little effect on gastric radioiodine secretion but increased total digestive tract radioiodine because of greater volume of tract contents. Inhibition of gastric radioiodine secretion by thiocyanate reduced the digestive tract radioiodine pool. The digestive tract iodine pool may conserve iodine by reducing loss in urine.

Introduction

Dairy cows fed low-iodine rations produced milk containing iodine in the range considered deficient, but milk yield was not reduced (14). This ability to maintain production during periods of minimal dietary iodine would require adjustments to conserve available iodine. Cows with extensive 131I thyroid irradiation damage yielded about half as much milk containing almost twice as much of a radioiodine dose as their normal identical twins (9). Exogenous thyroxine increased milk yields and reduced radioiodine concentrations in milk of both thyroid-damaged (9) and normal (12) cows. Thiocyanate (SCN), which had no immediate effect on milk yield, lowered milk radioiodine more than thyroxine (9).

Following administration of anions inhibiting iodide transfer, a decrease in milk iodide usually coincided with initially increased plasma and urinary iodine (3, 4, 9, 11). Concentration of circulating iodide by the abomasum is also inhibited by SCN (13). Previous investigators who reported blood-milk iodide interrelationships (3, 4, 9) and iodine excretion in feces and urine (11, 12) did not discuss these events in relation to iodine within the gastrointestinal tract.

We investigated (a) blood plasma radioiodine concentrations and fecal and urinary radioiodine excretions of thyroidectomized and thyroid-intact calves (with and without thiocyanate) and (b) effects of thyroid irradiation damage, exogenous thyroxine, and thiocyanate on radioiodine absorption and excretion in various sections of the digestive tracts of nonlactating cows. The objective was to study plasma iodine concentrations and excretory losses in relation to iodine cycling through the abomasum.

Experimental Procedures

In two trials effects of thyroidectomy and/or thiocyanate were investigated with four calves weighing 219 ± 74 kg (SD). Two Holstein bulls and two dairy-beef crossbred heifers of the same age were paired. After a preliminary 131I metabolism trial established that calves of each pair had similar 131I excretion patterns,
one calf of each pair was surgically thyroidec-

tomized.

**Trial 1.** During the first trial beginning 9 mo
after thyroideectomy of two calves, each calf
was given 40 µCi 125I (as NaI, carrier-free) in
a gelatin capsule by bailing gun daily for 6 wk.
Radioiodine was allowed to equilibrate for 2
wk, and experimental comparisons were made
in the last 4 wk. One pair, including an intact
and a thyroidectomized heifer, received 2 g
NaSCN daily during the 3rd and 5th wk of
125I administration. The other pair received the
same treatment during the 4th and 6th wk.
Feces, urine, and blood were sampled daily
immediately before 125I dosing.

**Trial 2.** Since the thyroidectomized bull
showed evidence of remaining thyroid activity
during the first trial, it was given 20 mCi 131I
to destroy residual thyroid tissue. Sufficient
time was allowed for excretion and physical
decay of the 131I to background amounts before
the second trial. Each calf was given a single
oral 1 mCi dose of 131I (carrier-free NaI); then
feces, urine, and blood were collected at 24-h
intervals for 5 days. The 6th day after 131I ad-
ministration each calf was given 5 g NaSCN orally.
Two grams NaSCN were given each calf daily during the following 5-
day collection of feces, urine, and blood. Plas-
ma samples were precipitated with NaOH-
ZnSO₄ (5) for measurement of protein-bound
radioiodine.

**Trial 3.** Iodine clearance by the kidney was
determined in two 290 kg heifers. Self-retain-
ing urinary catheters were inserted before the
heifers were dosed intravenously with 250 µCi
131I as carrier-free NaI. Urine flowing from
catheters was collected in graduated cylinders
for one 90-min period during the 1st day and
for three consecutive 20-min and one 240-min
periods on each of the 2nd, 3rd, and 4th days
after dosing. Blood samples were drawn from
jugular vein canulas at the midpoint of the
20-min collections and at the beginning and
end of longer collections. On the 6th day after
131I administration, each heifer was dosed intra-
venously with 70 ml 1 M NaSCN and 250 µCi
125I (carrier-free NaI). Each heifer received 5
g NaSCN by gelatin capsule daily for 4 days.
Clearance of 125I was measured in the same
manner and at the same times as in prelimi-
nary 131I dosing. Kidney clearances of radioio-
dine (Cₖ) were calculated by the formula: Cₖ
= (% of radiiodine dose per ml urine × ml
urine per min)%/ of radiiodine dose per ml
of plasma. Total urine was also collected and
sampled daily during 4 days after dosing.

**Trial 4.** Twenty-eight nonlactating cows
were used to investigate effects of SCN and
thyroid status on absorption and gastric secre-
tion of radioiodine. Experimental animals in-
cluded one 518 kg Brown Swiss, four 398 ±
171 (SD) Guernseys, five 460 ± 69 kg Here-
ford-dairy breed crosses, six 405 ± 46 kg Jer-
seys, and twelve 418 ± 147 kg Holsteins. Thy-
roid glands of 14 cows had been damaged by
previous 131I irradiation (9), and 14 cows had
apparently normal thyroid function. Four thy-
roid-damaged cows were fed 8 g thyroprotein³
daily for 60 days, and two thyroid-intact cows
were given 10 g NaSCN by bailing gun daily,
beginning with the first radioiodine dose.

Cows were given daily oral doses of 50 to
100 µCi radioiodine (Na125I or Na131I) and a
nonabsorbed reference element (144Ce144Pr or

**Table 1.** Effect of thyroidectomy and thiocyanate on iodine metabolism of calves.

<table>
<thead>
<tr>
<th>Trial and item</th>
<th>Thyroid-intact</th>
<th>Thyroidectomized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCN</td>
<td>Control</td>
</tr>
<tr>
<td>Daily dose trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feces (% of daily dose)</td>
<td>33.0*</td>
<td>34.2</td>
</tr>
<tr>
<td>Urine (% of daily dose)</td>
<td>54.1</td>
<td>34.0</td>
</tr>
<tr>
<td>Blood plasma total radioiodine (% of daily dose/liter)</td>
<td>.73</td>
<td>.74</td>
</tr>
<tr>
<td>Plasma protein-bound radioiodine (% of total radioiodine)</td>
<td>55.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Single dose trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feces (total % of dose)</td>
<td>31.0*</td>
<td>38.0</td>
</tr>
<tr>
<td>Urine (total % of dose)</td>
<td>47.4</td>
<td>35.8</td>
</tr>
</tbody>
</table>

* Averages of two trials with four calves.

* Averages of four calves.
**Results**

**Trial 1.** Effects of thyroid status and thiocyanate on radioiodine metabolism of calves given daily radioiodine doses are in Table 1. Thyroidectomized calves excreted 49% less 125I in feces (P < .07) and 42% more in urine (P < .05) than intact calves. Thiocyanate reduced fecal 125I 44% in thyroidectomized calves but less than 4% in intact calves. Urinary 125I excretions increased 59% in intact and 28% in thyroidectomized calves when SCN was fed. Effects of either thyroid status or SCN on concentration of 125I in plasma or in Zn(OH)2 precipitates (5) of plasma were negligible. No interactions of thyroid status by SCN were significant.

**Trial 2.** Following single radioiodine doses, fecal radioiodine excretion was 52% less (P < .05) for thyroidectomized animals during the SCN period, but the 18% decrease in fecal radioiodine for intact calves was not statistically significant (Table 1). Urinary radioiodine excretions were increased 32% (P < .05) in intact and 36% (P < .05) in thyroidectomized calves by SCN feeding. Radioiodine excretions were lower in feces and higher in urine for thyroidectomized as compared to intact calves.

Plasma radioiodine concentration was higher (P < .05) and the percentage of total radioactivity in protein-bound form was lower (P < .05) during the SCN period than in the preliminary period for thyroidectomized calves (Fig. 1). Although plasma radioiodine was also higher during the first 3 days of the SCN period for intact calves, average differences between SCN and control periods were not statistically significant. The percentages of plasma radioiodine precipitable by Zn(OH)2 were also lower during the SCN period for intact calves; however, differences were nonsignificant.

**Trial 3.** Thiocyanate caused a 10% increase in the rate of loss of radioiodine from plasma measured by regression of logarithm of concentration in plasma as a function of time after dosing (Table 2). Kidney clearance of radioiodine was 52% higher (P < .05) during SCN administration than in the preliminary period,

![Graph](image-url)

**Fig. 1.** Effect of thyroid status and thiocyanate on concentration and protein-binding of radioiodine in plasma following intravenous administration to calves.

**Table 2.** Effect of thiocyanate on plasma radioiodine concentration, kidney clearance of radioiodine, urine flow rate, and total recovery of radioiodine in urine of two heifers.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Preliminary</th>
<th>SCN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma radioiodine (% of dose/liter)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero time</td>
<td>.61</td>
<td>.70</td>
</tr>
<tr>
<td>96 hr after dosing</td>
<td>.15</td>
<td>.12</td>
</tr>
<tr>
<td>Percentage decline per hr (%)</td>
<td>.78</td>
<td>.86</td>
</tr>
<tr>
<td>Kidney clearance (ml plasma/min)*</td>
<td>20.5 ± 2.2</td>
<td>31.4 ± 2.1</td>
</tr>
<tr>
<td>Urine flow rate (ml/min)*</td>
<td>4.6 ± .1</td>
<td>4.8 ± .3</td>
</tr>
<tr>
<td>Total 96 hr urinary radioiodine (% of dose)*</td>
<td>38.4</td>
<td>49.6</td>
</tr>
</tbody>
</table>

*Calculated by least squares from regression of log plasma radioiodine concentrations with hour after dosing.

*Two calf averages of single determinations.

*Mean ± standard error of 13 observations on each of two calves.
Table 3. Effect of thyroid status on content weight, radioiodine concentration, and total radioiodine in contents of the bovine digestive tract.

<table>
<thead>
<tr>
<th>Measurement and section of tract</th>
<th>Treatment and number of cows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thyroid intact (12)</td>
</tr>
<tr>
<td>Contents weight (% of body weight)</td>
<td>7.4 ± 0.7a</td>
</tr>
<tr>
<td>Rumen-reticulum</td>
<td>1.4 ± 0.1</td>
</tr>
<tr>
<td>Omasum</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Abomasum</td>
<td>1.1 ± 0.2</td>
</tr>
<tr>
<td>Small intestine</td>
<td>0.5 ± 0.1</td>
</tr>
<tr>
<td>Cecum</td>
<td>0.6 ± 0.1</td>
</tr>
<tr>
<td>Large intestine</td>
<td>11.4 ± 1.0</td>
</tr>
<tr>
<td>Total radioiodine (% of daily dose)</td>
<td>21.0 ± 4.3</td>
</tr>
<tr>
<td>Rumen-reticulum</td>
<td>6.8 ± 1.6</td>
</tr>
<tr>
<td>Omasum</td>
<td>18.4 ± 2.6</td>
</tr>
<tr>
<td>Abomasum</td>
<td>16.5 ± 2.2</td>
</tr>
<tr>
<td>Small intestine</td>
<td>6.3 ± 0.9</td>
</tr>
<tr>
<td>Cecum</td>
<td>6.9 ± 0.6</td>
</tr>
<tr>
<td>Large intestine</td>
<td>75.9 ± 5.9</td>
</tr>
</tbody>
</table>

a Mean ± standard error.

but rate of urine flow during these measurements did not differ (P > .10). Recovery of radioiodine in urine during 96 h after dosing was 29% higher with SCN than in the preliminary period.

Trial 4. At slaughter 16 h after the last radioiodine dose, higher percentages of the daily intake were recovered from every section of the digestive tract except the omasum in thyroid-damaged as compared to intact-control cows (Table 3). This resulted from higher radioiodine concentrations as well as increased volume of contents in the rumen, abomasum, and large intestine. Rumen and abomasal radioiodine contents were reduced to control in thyroid-damaged cows fed thyroprotein. Markedly less abomasal radioiodine was recovered from the two cows fed SCN, probably because of its inhibitory effect on gastric concentration of iodine (13).

Net secretion of radioiodine into the abomasum was calculated from relative concentrations of radioiodine and the nonabsorbed reference element (1). Percentages of radioiodine doses cycled through the abomasum daily were: thyroid-intact, 468 ± 58 (SE); intact fed SCN, 64; thyroid-damaged, 506 ± 123; and thyroid-damaged fed thyroprotein, 372 ± 123 (Fig. 2). Thyroid damage or thyroprotein feeding had little effect on gastric radioiodine secretion. Inhibition of gastric radioiodine secretion by SCN greatly reduced the abomasal pool and was evident in lower radioiodine recoveries from the remaining intestinal tract.

Discussion

The four experiments showed that effects on radioiodine metabolism shared by both hypothyroidism and SCN (although not always to the same degree) were (a) elevated concentrations in plasma (Fig. 1), (b) reduced plasma protein-bound radioiodine (Fig. 1), (c) higher excretion in urine, and (d) lower excretion in feces (Tables 1 and 2). Differences are (a) gastric secretion of radioiodine was sharply reduced by SCN, but hypothyroidism had no apparent effect (Fig. 2); and (b) total radioiodine in digestive tract contents was markedly reduced by SCN but greatly increased by hypothyroidism (Table 3).
Fig. 2. Effect of thyroid status and thiocyanate on apparent absorption and excretion of radioiodine in different sections of the bovine digestive tract. Values less than zero represent disappearance (absorption) while those above zero represent addition (secretion) of radioiodine.

Higher urinary and lower fecal radioiodine excretions by thyroidectomized calves (Table 1) probably resulted from lower protein-bound radioiodine as a percentage of total plasma radioiodine (Fig. 1). Radioiodine administered as labeled thyroxine is excreted primarily in feces (12); but when given as iodide, urinary excretion predominates. Inhibition of thyroid function by SCN with an accompanying increase in the percentage of nonbound iodine could explain increased urinary iodine loss in intact but not in thyroidectomized calves.

A high proportion of total circulating iodine in thyroid-damaged cows (Table 1) probably resulted from lower protein-bound radioiodine as a percentage of total plasma radioiodine (Fig. 1). Radioiodine administered as labeled thyroxine is excreted primarily in feces (12); but when given as iodide, urinary excretion predominates. Inhibition of thyroid function by SCN with an accompanying increase in the percentage of nonbound iodine could explain increased urinary iodine loss in intact but not in thyroidectomized calves.

The abomasum is a major site for reentry of circulating iodine into the bovine digestive tract (1, 15). Over 65% of intravenously injected radioiodide was recovered in material draining from cannulas placed in ligated bovine abomasum during 6 h after administration (15). Secretion of iodine into abomasal contents (Fig. 2) was estimated from its ratio to a nonabsorbed reference element at slaughter 16 h after the last dose. Advantages and shortcomings of this technique have been discussed by Cragle (2). If iodine accumulated at time of slaughter was representative of the 24 h between daily doses, over 50% of the daily intake could have been cycled through the abomasum daily.

Iodine secreted into the abomasum is reabsorbed from the small intestine (1). Lewitus and Shaham (6) consider the gastric stomach to be a reservoir which concentrates plasma iodine and then gradually returns it to plasma for uptake by the thyroid. Anions which inhibit iodine concentrating systems usually increase plasma iodine (3, 4, 9). Elevated plasma iodine is often accompanied by higher urinary iodine (3, 11). If loss of iodine in urine is largely dependent on plasma iodide (10), blockage of abomasal iodine concentration by SCN could account for elevated urinary losses (Tables 1 and 2).

Iodine concentrating action of the abomasum may promote conservation of iodine by transferring it from vascular to extravascular compartments, thus preventing its excessive loss in urine. Cattle apparently can adjust to low iodine intakes by reducing iodine losses in milk, urine, and feces (10, 14). Cycling of iodine through the abomasum undoubtedly also plays an important role in conservation of iodine.

References

(6) Lewitus, Z., and Y. Shaham. 1971. Extrathyroidal iodine concentration pool as a first stage in thyroidal iodine uptake in the lizard. In Further Advances Thyroid Res,


