This is to certify that the

thesis entitled

IODINE TOXICOSIS IN HOLSTEIN HEIFER CALVES: CLINICAL AND LABORATORY DATA

presented by

James R. Main

has been accepted towards fulfillment of the requirements for

M.S. degree in *Large Animal Surgery and Medicine*

Major professor

Date *September 17, 1981*

O-7639

IODINE TOXICOSIS IN HOLSTEIN HEIFER CALVES:

CLINICAL AND LABORATORY DATA

By

James R. Main

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Large Animal Surgery and Medicine

1981

ABSTRACT

IODINE TOXICOSIS IN HOLSTEIN HEIFER CALVES: CLINICAL AND LABORATORY DATA

By

James R. Main

A study was undertaken to determine the clinical signs of iodine toxicity. Accompanying clinical pathological laboratory data are also reported.

Forty Holstein heifer calves, with an average body weight of 120 kg, were divided into 4 groups of 10 animals each. Calves in Group I were the controls, receiving maintenance levels of iodine; Groups II, III, and IV received daily oral doses of 50, 250, and 1250 mg of iodine daily, per animal, respectively. The trial period was 6 months.

Blood samples collected at regular intervals were used for the following determinations: cell counts, hemoglobin, blood urea nitrogen, serum calcium, phosphorus, magnesium, glutamic oxalacetic transaminase, sorbital dehydrogenase, hydroxybutyric dehydrogenase, and alkaline phosphatase. Serum immunoglobulins were also measured.

Calves in Groups I (control) and II (50 mg) did not show clinical signs of iodine toxicosis and clinical pathological laboratory data from them were normal.

Clinical findings in calves from Groups III (250 mg) and IV (1250 mg) were profuse nasal and lacrimal discharge, bronchopneumonia, poor weight gains, skin lesions, and rough hair coat. After 5 months of daily oral dosing, there was remission of the above clinical signs.

Abnormal clinical pathological laboratory data were noted primarily in Groups III (250 mg) and IV (1250 mg). Significantly lower ($p \leq 0.05$) serum calcium, phosphorus, and magnesium values were found in Group IV (1250 mg). Lower red blood cell counts and hemoglobin levels were also present in this group. In Groups III (250 mg) and IV (1250 mg), significantly lower ($p \leq 0.05$) serum glutamic oxalacetic transaminase, sorbital dehydrogenase, and hydroxybutyric dehydrogenase values were found.

It was concluded that clinical signs of iodine toxicosis were related mainly to the respiratory and integumentary systems, and these signs subsided after prolonged feeding of the same level of iodine. The toxic dose of iodine seems near 200 to 250 mg daily.

DEDICATED TO

Valarie J. (Tobias) Main

ACKNOWLEDGEMENTS

I wish to express gratitude to the following people who gave me their counsel, advice, and help in preparing this thesis, and for making it possible to conduct the research in the Department of Large Animal Surgery and Medicine, Michigan State University.

Dr. G. H. Conner: Professor, Department of Large Animal Surgery and Medicine.

Dr. H. Stowe: Associate Professor, Department of Large Animal Surgery and Medicine.

Dr. C. H. Coy: Associate Professor, Department of Large Animal Surgery and Medicine.

Dr. G. R. Carter: Professor, Department of Microbiology and Public Health.

Dr. S. M. Getty, Associate Professor, Department of Large Animal Surgery and Medicine.

Dr. W. F. Riley: Professor and Chairman, Department of Large Animal Surgery and Medicine.

Ms. Roberta Milar: Medical Technologist, Department of Large Animal Surgery and Medicine.

Dr. D. L. Haggard: Instructor, Department of Large Animal Surgery and Medicine.

Dr. J. D. Krehbiel: Director, Clinical Pathology, Department of Pathology.

I also thank the faculty and staff in the Departments of Dairy Science and Pathology, Michigan State University, East Lansing, Michigan, for their cooperation. Financial support for this study was received from the Michigan Agricultural Experiment Station.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

INTRODUCTION

It is judged that the use of excessive iodides may be a widespread feeding practice in Michigan cattle. Feed mills and salesmen (Matovinovic, 1974) seem to be promoting the use of iodides in rations or as supplements for the treatment or prevention of "foot-rot", respiratory disease, "lumpy jaw" (*Actinomyces bovis*), mastitis and other diseases.

For years, veterinarians have been aware of possible acute toxic reactions in cattle when body levels of iodide become elevated. Symptoms of such toxicity include profuse nasal discharge and lacrimation, coughing, tremors, scaly skin, and sometimes abortions.

Today, another form of iodism has been reported: chronic toxicity associated with the feeding of iodized salt, mineral supplements containing organic iodides, or medicated feed supplements with molasses and iodides.

In a study of 15 herds of Michigan dairy cattle suffering from excessive intakes of iodine, Hillman et al. (1976) reported clinical histories of discharges from the eyes and nose, suggestive of pneumonia.

Complaints of low milk production and poor health in an additional 19 herds of Michigan dairy cattle were investigated by Hillman et al. (1976). The cattle were being fed iodine as ethylenediamine-dihydriodide (EDDI) at the rate of 90 to 235 mg per head per day for periods of time varying from 6 months to 2 years. Clinical histories were decreased milk production, loss of body weight, failure to rebreed normally, and failure of calves to grow normally.

This study was designed to investigate the clinical signs and clinical pathological laboratory parameters seen with feeding various levels of iodides to dairy heifer calves.

LITERATURE REVIEW

All body tissues and secretions contain iodine, and there is little doubt it occurs in all cells. Seventy to eighty percent of the total iodine is found in the thyroid gland, where it is used for synthesis of thyroid hormones (Elmer, 1960). Significant amounts of iodine have also been found in the ovary, adrenal cortex, parathyroid and pituitary (Salter, 1940).

Iodine is absorbed chiefly from the small intestine and circulated as inorganic and organic iodine (Wohl and Goodhard, 1960). It enters the thyroid as iodide ion. Iodide is also concentrated by salivary glands, the gastrointestinal tract, and hair follicles. The abomasum is a major site for reentry of circulating iodine into the bovine digestive tract (Miller et al., 1972).

The main pathway of excretion of iodide is the urine (Elmer, 1960). Some is excreted in saliva and sweat. Significant quantities of iodine are found in milk. In cows, colostrum is several times higher in iodine than later milk (Underwood, 1977) and there is a fall in concentration in later lactation.

Webster et al. (1957) found the oral LD_{50} of iodine as potassium and sodium iodide in rats to be about 2 mg per kg body weight. The corresponding iodates were twice as toxic as the iodides.

For years, veterinarians have been aware of possible toxic reactions in cattle when body levels of iodide became elevated. Symptoms of such toxicity included profuse nasal discharge and lacrimation, coughing, tremors, scaly skin, and sometimes abortions.

Today, another form of iodism has been reported: chronic toxicity associated with the feeding of iodized salt, mineral supplement containing organic iodides, or medicated feed supplements with molasses and iodides. Some feed mills promote the use of iodides in rations of dairy cows for the prevention of "foot-rot", respiratory disease, mastitis, actinomycosis ("lumpy jaw"), actinobacillosis ("wooden tongue"), and other disease conditions.

Miller and Swanson (1967, 1969) dosed dairy cattle with radioactive iodine (^{131}I) and studied the effects of hypothyroidism. They reported reduced milk yield, rough hair coat and reduced appetite. Calves born from cows dosed with radioactive iodine appeared normal at birth but failed to grow properly. In tracer studies on the metabolism of iodine, Miller and Swanson (1972) observed ethylenediamine dihydriodide (EDDI) to be absorbed in amounts equal to or greater than sodium iodide and longer retention in cartilage and soft tissues. They concluded that EDDI left the rumen metabolized differently than sodium iodide.

Iodine toxicity was reported in herds of beef and dairy cattle in Minnesota by McCauley and Johnson (1972). Main findings were severe bronchopneumonia, tracheitis, and coughing. Also, cattle fed high levels of iodine appeared more susceptible to common infections and responded poorly to routine therapy. Ethylenediamine dihydriodide was implicated in most cases being fed in excessive levels with a mineral supplement. Levels as high as 250 to 300 mg EDDI were being fed daily to some animals, mostly yearling steers. If EDDI were fed for a short period of time (1 to 2 weeks) and then discontinued, symptoms disappeared in 3 to 4 weeks. One farmer lost 420 of 800 feedlot steers as a result of excessive iodine feeding and concomitant infections. McCauley indicated the aggravation of clinical conditions of animals receiving EDDI appeared to be related to the degree of stress, infections, dosage of iodine, and length of time it had been given.

Hamilton and Geever (1952), Kolmer (1961), and Stone and Willis (1967) have reported that the administration of iodine to man and animals undergoing acute infections and noninfectious insults results in the manifestations of a more severe clinical picture.

Miller and Swanson (1967) observed the iodine concentration in the circulation of the bovine fetus was over 5 times that found in the plasma of the dam. The authors concluded the fetus was unable to excrete iodine via the urinary pathway.

Acute iodine toxicity in laboratory animals (mice, rats) is apparently produced only by feeding massive doses of iodine (50 to 500 mg/kg body weight) (Fisher and Carr, 1974).

Wallace (1975) reported iodine toxicity in Georgia dairy herds. Signs were decreased milk production, persistent coughing, lameness, and overgrown hooves. Average daily intake of iodine was estimated to be 107 mg. The daily iodine requirement for the average lactating dairy cow is 9 to 10 mg.

Drew and Williams (1975) reported the effect of excess dietary iodine on pregnant mares and their foals. Four foals were born with greatly enlarged thyroids and leg weakness. Two died shortly after birth and the others subsequently recovered. The thyroids from the dead foals were hyperplastic. Feed analysis showed the mares had a daily iodine intake of 83 mg during gestation. Also, the mares had elevated levels of serum protein-bound iodine. Increased mortality of newborns has been reported in rats fed excessive levels of iodine during gestation.

McCauley et al. (1973) experimentally induced iodine toxicosis in lambs. They fed EDDI or potassium iodide (KI) in amounts ranging from 94 to 785 mg/day/lamb for 3 weeks. Several lambs given large dosages of iodide died with marked lesions of bronchopneumonia. The authors suggested excessive iodine may affect the inflammatory response mechanism of animals with existing acute or chronic infection.

Newton et al. (1974) reported that calves fed 100 or 200 ppm of calcium iodate in their ration coughed and had a profuse nasal discharge. He determined the minimum toxic iodine level to be near 50 ppm daily. Lower blood hemoglobin and serum calcium were noted in the high groups.

MATERIALS AND METHODS

Animals and Experimental Design

Forty Holstein heifer calves were purchased from two farms near Indianapolis, Indiana. They weighed approximately 110 kg each upon arrival. All animals were housed under the same conditions and given identical diets, except for the level of iodide. Three to four animals were housed in each pen. The diet consisted of 0.9-1.3 kg of commercial calf pellets[a] daily and second cutting alfalfa hay free choice. Water was available at all times. Feed material and water were analyzed to determine the level of iodine (Table 1).

Table 1. Iodine content of feed and water consumed by heifers on iodine toxicity experiment

Sample	Total Iodine (dry matter basis)
Alfalfa hay	0.098 μg/gm
Grain	1.32 μg/gm
Water	0.002 μg/ml

[a]Ralston Purina Company, St. Louis, MO: "Milk Chow Special", 14% protein with added iodine of 0.35 ppm.

During a 3-week pre-trial period, fat biopsies were taken around the tail head of all animals to test for polybrominated biphenyl (PBB). Levasole[R] [b] (levamisole hydrochloride), an anthelmintic, was given subcutaneously to each calf at the rate of 2.0 cc/45.5 kg body weight. Vitamin A[c] (1,000,000 IU), vitamin D[c] (150,000 IU), vitamin E[d] (272 IU), and selenium[d] (8.8 mg) were given intramuscularly shortly after arrival. All animals were given *Brucella abortus* Strain 19 and *Leptospira* bacterin containing *L. hardjo, L. pomona,* and *L. grippotyphosa*.[e]

The calves were randomly divided into 4 groups of 10 each. Group I was the control group. They received a daily oral dosing (drench) of tap water. Groups II, III and IV received a daily oral dosing of water in which sufficient EDDI was dissolved to make a dose of 50, 250 and 1250 mg of iodine, respectively. All animals were observed daily for any clinical signs or symptoms of disease. All feed that was not eaten was weighed daily. Body weights were taken monthly for all animals.

Blood samples were taken by jugular venipuncture at the following periods of time: 1 week prior to dosing of iodine and 1, 2, 4, 16 and 20 weeks after daily oral dosing with iodine started. The blood was used to determine the following clinical pathological parameters:

---

[b]Pitman-Moore Company, Washington Crossing, NJ: "Levasole" (levamisole hydrochloride), 18.2% injectable solution.

[c]Pfizer, Incorporated, New York, NY: "Vitamin A & D Injectable."

[d]Burns-Biotec Company, Oakland, CA: "BoSe."

[e]Affiliated Laboratories, Division of Whitmoyer Labs, Incorporated, Horsham, PA.

Complete blood count (CBC)

- erythrocytes[f]
- leukocytes[f]
- total protein[g]
- hemoglobin[h]
- packed cell volume[i]

Blood urea nitrogen (BUN)[j]

Serum calcium[k]

Serum phosphorus[l]

Serum magnesium[m]

Alkaline phosphatase[n]

Hydroxybutyric dehydrogenase (HBD)[n]

Serum glutamic oxalacetic transaminase (SGOT)[n]

Sorbital dehydrogenase (SDH)[n]

Serum immunoglobulins (IgG, IgA, IgM)[o]

---

[f] Coulter Blood Counter, Coulter Electronics, Incorporated, Hialeah, FL.

[g] Goldberg Refractometer, T. S. Meter, American Optical Company, Buffalo, NY.

[h] Fisher Scientific Company, Pittsburgh, PA.

[i] Microhematocrit method.

[j] Urograph[R] - Warner Chilcott, Morris Plains, NJ.

[k] Oxford, Titrator Reagen Set, Oxford Laboratories, 1149 Chess Drive, Foster City, CA.

[l] Hycel Phosphorus Test, Hycel, Incorporated, P.O. Box 36329, Houston, TX.

[m] LaMotte Magnesium Reagent, LaMotte Chemical Products, Charleston, MD.

[n] Hycel, Incorporated, P.O. Box 36329, Houston, TX.

[o] Miles Laboratories, Elkhart, IN.

RESULTS AND DISCUSSION

Laboratory Data

The mean red blood cell counts (RBC) for each group are presented in Table 2. In all groups, the mean RBC count declined during the course of the experiment. Significant differences ($p \leq 0.05$) were found in Group IV during the last 4 months of the experiment, as compared to each of the other groups. Iodine toxicosis may interfere with RBC production by depressing hematopoiesis in the bone marrow.

Hemoglobin values for all groups are presented in Table 3. Significantly lower values ($p \leq 0.05$), as compared to the other groups, were most evident in Group IV during the last 4 months of the trial period. Again, iodine toxicosis may interfere with hematopoiesis.

Mean white blood cell counts (WBC) are found in Table 4. Groups III and IV had lower mean values than Groups I and II, but significant differences ($p \leq 0.05$) were noted only at +1 week and +4 weeks of the trial period. White blood cell depression may cause increased susceptibility to disease, by suppressing the immune system.

Mean serum calcium values are in Table 5. Group IV had a significant ($p \leq 0.05$) lower mean serum calcium, during the last 4 months of the trial period, than the other groups. Iodine toxicosis appears to interfere with calcium metabolism. Thyroid dysfunction is a possible explanation. Also, iodine may compete with calcium for binding on serum proteins used in transport mechanisms.

Table 2. Mean red blood cell counts for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1] 0	50	250	1250
		($10^6/mm^3$)		
-1	10.01±0.66[a2]	9.22±1.42[b,c]	9.64±1.13[a,c]	10.20±1.01[a,c]
1	9.54±1.01[a]	9.10±1.13[a]	8.34±1.23[a]	8.20±3.02[b]
2	8.92±0.93[a]	8.56±1.12[a]	8.45±1.40[a]	8.45±0.98[a]
4	8.89±0.99[a]	8.97±1.24[a]	8.37±1.08[a]	7.98±2.91[b]
8	9.37±2.40[a]	9.08±1.76[a,c]	8.66±1.04[b,c]	8.63±3.18[a]
16	8.36±0.84[a]	7.78±0.59[a]	7.56±0.72[a]	6.57±3.49[b]
20	7.94±0.74[a]	7.16±2.54[b]	7.88±0.81[a]	6.51±3.48[b]
Combined $\overline{X}$	8.99±1.32	8.55±1.62	8.41±1.20	8.09±2.91

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 3. Mean hemoglobin levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	10.70±0.73[a2]	10.90±1.23[a]	11.60±1.32[a]	11.70±0.86[a]
1	10.90±0.67[a]	11.10±1.03[a,b]	10.40±1.35[b,d]	9.70±3.49[b,c]
2	10.30±0.61[a]	10.40±0.69[a]	10.50±1.07[a]	10.40±0.99[a]
4	10.50±0.76[a]	11.40±1.11[a]	10.30±0.65[a]	8.30±3.30[b]
8	11.20±0.94[a]	11.40±0.86[a]	10.70±0.80[a,c]	10.30±3.64[b]
16	10.70±0.84[a]	10.50±0.71[a]	10.80±0.81[a]	8.35±4.42[b]
20	11.10±0.75[a]	10.30±3.72[b]	11.40±0.81[a]	8.90±4.74[b]
Combined $\overline{X}$	10.77±0.79	10.84±1.64	10.80±1.07	10.80±3.39

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-d]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 4. Mean white blood cell counts for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		($10^3/mm^3$)		
-1	10.20±1.63[a2]	9.22±2.02[a,b]	9.10±2.50[a,c]	8.20±1.01[a]
1	10.00±2.24[a]	9.00±1.29[a,b]	10.30±3.15[a]	6.06±2.98[b,c]
2	8.22±1.58[a]	7.90±1.40[a]	7.70±1.65[a]	5.90±1.22[a]
4	9.10±2.23[a]	8.46±1.30[a,b]	7.70±2.14[a]	5.87±2.59[a]
8	10.80±2.05[a]	10.46±1.81[a]	8.70±1.70[a]	5.90±2.27[a]
16	10.50±1.76[a]	9.24±2.61[a]	8.70±2.34[a]	5.52±3.00[a]
20	11.90±2.06[a]	9.13±3.67[a]	10.20±2.25[a]	6.15±3.54[a]
Combined $\bar{X}$	10.11±2.16	9.11±2.24	8.90±2.40	6.22±2.50

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-d]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 5. Mean serum calcium levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	11.90±1.56[a2]	11.50±0.85[a]	10.50±4.16[b]	10.60±0.99[a]
1	9.70±0.90[a]	10.00±0.83[a]	9.70±1.19[a]	9.60±0.77[a]
2	9.90±0.57[a]	9.70±0.83[a]	10.00±1.95[b]	9.20±1.54[b]
4	10.20±0.90[a]	10.55±0.59[a,b]	10.10±1.25[a]	7.12±2.58[b]
8	10.90±0.74[a]	9.80±0.75[a]	9.90±1.07[a]	7.86±4.21[b]
16	10.60±0.95[a]	10.60±1.30[a]	11.50±0.23[a]	8.10±4.35[b]
20	10.40±0.89[a]	10.20±1.15[a]	9.80±0.63[a]	7.19±3.85[b]
Combined $\bar{X}$	10.51±1.15	10.34±1.19	10.20±1.96	8.53±3.10

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a,b]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

The mean serum phosphorus values are shown in Table 6. All groups had their lowest recorded phosphorus 1 week after oral dosing with iodine. Serum phosphorus values were significantly lower ($p \leq 0.05$) in Group IV than in the other groups. Again, thyroid function and transport mechanisms may be impaired.

Magnesium levels are shown in Table 7. Mean values for Groups I and III are normal. However, below normal levels are seen in Groups II and IV. In Group II, the mean magnesium level was below 2.0 mg/dl on 2 time periods (1.98 at -1 week and 1.84 at +2 weeks). For Group IV, a mean value of 1.9 mg/dl was reported on the fourth week of the trial period. Group IV showed a significant decline ($p \leq 0.05$) in mean serum magnesium, as compared to the other groups, during the last 4 months of the experiment. There were no clinical signs of hypomagnesemia in any groups during the trial period. Iodine toxicosis may interfere with magnesium absorption.

Mean blood urea nitrogen (BUN) levels, in Table 8, are normal for all groups.

Between groups, body weights varied greatly (Table 9). Group I and II body weights were very similar. Group I had an average daily gain of 0.80 kg; Group II had an average daily gain of 0.78 kg. At the end of the 6-month trial period, animals in Group III weighed an average of 18.18 kg less than animals in Groups I and II. Calves in Group IV averaged 45.45 kg less than controls. Group III had an average daily weight gain of 0.67 kg, and Group IV gained 0.59 kg daily. Excessive iodine appears to retard growth by reducing appetite. Depression of hematopoiesis is a possible mechanism.

The mean hydroxybutyric dehydrogenase (HBD) values are seen in Table 10. This enzyme is specific for myocardial degeneration.

Table 6. Mean serum phosphorus values for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	8.30±0.97[a2]	7.90±1.02[a]	7.20±2.73[b]	7.50±0.67[a]
1	7.00±1.10[a]	6.90±1.55[a,b]	7.20±0.71[a]	6.80±1.06[a,b]
2	7.00±1.30[a]	7.00±0.73[a]	6.60±0.44[b]	6.90±1.18[a]
4	7.70±0.87[a]	7.60±1.17[a,b]	7.90±0.99[a]	7.60±2.87[b,c]
8	8.50±0.92[a]	7.00±1.82[a,b]	8.60±1.05[a]	6.12±3.36[b]
16	9.00±0.53[a]	8.40±1.38[a,b]	7.70±0.91[a]	6.48±3.54[b,c]
20	8.30±0.61[a]	8.70±1.05[a]	7.00±0.78[a]	6.00±2.21[b]
Combined $\overline{X}$	7.98±1.15	7.61±1.40	7.44±1.38	6.77±2.50

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 7. Mean serum magnesium levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	2.70±0.25[a2]	1.98±0.59[b]	2.14±0.88[b]	2.50±0.45[a]
1	2.40±0.55[a]	2.33±0.33[a]	2.40±0.55[a]	2.90±0.64[a]
2	2.10±0.66[a]	1.84±0.44[a]	2.40±0.33[a]	3.00±0.50[a]
4	2.40±0.31[a]	2.08±0.60[a,b]	2.30±0.79[b]	1.70±0.73[b]
8	2.30±0.20[a]	2.44±0.40[a,b]	2.80±0.58[b,c]	1.70±1.00[b,c]
16	2.20±0.62[a]	2.34±0.60[a,b]	2.60±0.34[a,c]	2.00±1.33[a]
20	2.50±0.52[a]	2.75±0.27[a]	2.70±0.41[a]	2.30±1.26[b]
Combined $\overline{X}$	2.36±0.49	2.25±0.54	2.49±0.61	2.30±1.00

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 8. Mean blood urea nitrogen levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1] 0	50	250	1250
		(mg/dl)		
4	14.00±1.43[2]	13.30±1.16	12.50±0.97	11.80±4.26
8	14.00±1.37	12.80±1.32	13.20±0.55	13.40±5.85
16	15.00±0.95	14.00±1.16	13.90±1.29	13.30±5.76
20	15.00±0.47	15.30±0.95	15.30±0.82	14.50±6.30
Combined $\overline{X}$	14.50±1.06	13.90±1.15	13.73±1.16	13.25±5.52

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

Table 9. Mean body weights for groups of calves supplemented at different iodine levels for 6 months

Months on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(kg)		
1	122	122	126	115
2	135	136	132	117
3	181	181	171	144
4	206	206	197	164
5	238	231	221	191
6	266	263	247	220

[1]As ethylenediamine dihydriodide (EDDI).

Table 10. Mean hydroxybutyric dehydrogenase values for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(IU/liter)		
-1	1238±131.51[a2]	1235±189.55[a]	1368±102.10[a]	1357±174.10[a]
1	1281± 84.30[a]	1242±159.33[a]	991±125.00[a]	893±112.00[a]
2	1297± 59.40[a]	1265± 86.29[a]	1339±203.20[b]	1321±384.90[b]
4	1168± 83.41[a]	946±377.54[a]	1039±129.40[a]	1025±371.50[b]
8	1047± 91.94[a]	1081±135.39[a,b]	1073±174.00[a]	897±374.30[b,c]
16	1143± 79.74[a]	1103±101.04[a]	1078±184.00[b,c]	786±430.80[b]
20	1307±121.86[a]	1351± 89.60[a]	1368±154.60[a]	1004±545.30[b]
Combined $\overline{X}$	1211±128.40	1175±221.00	1179±218.20	1151±270.61

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Significantly lower values ($p \leq 0.05$) were noted in Group IV than in the other groups during the last 5 months of the trial period.

Mean serum glutamic oxalacetic transaminase (SGOT) levels are shown in Table 11. Significantly lower values ($p \leq 0.05$) are noted in Groups II, III and IV during the trial period as compared to the controls. The normal values are 31-70 IU/liter.

Alkaline phosphatase values for each group are shown in Table 12. This enzyme is found in the liver, kidney, spleen, intestinal mucosa, and bone. Normal values are 19-68 IU/liter. Young growing animals may have higher levels. All groups have slightly above normal values.

Sorbital dehydrogenase (SDH) is a good indicator of hepatic function. Normal serum values are 12-21 IU/liter. Table 13 illustrates the SDH levels by calf group. Some significantly lower values ($p \leq 0.05$) are noted in Groups II, III and IV, as compared to the control group.

Mean serum immunoglobulin levels (IgG, IgM, IgA) for each group are found in Tables 14, 15, and 16, respectively. No significant differences were noted.

Fat biopsy results for polybrominated biphenyl (PBB) are shown in Table 17. All values are below the tolerance (0.03 ppm) established by the Michigan Department of Agriculture. PBB assays were conducted because symptoms of PBB and iodine toxicosis were found to be similar and to be assured these calves were not PBB contaminated.

In summary, abnormal clinical pathological laboratory findings were noted in Groups III and IV. Significant lower mean values ($p \leq 0.05$) were found for serum calcium, phosphorus, and magnesium in Group IV as compared to the other groups. Red blood cell (RBC) and hemoglobin levels were also lower in Group IV. Some significantly lower mean values ($p \leq 0.05$) were found for serum sorbital dehydrogenase, glutamic

Table 11. Mean serum glutamic oxalacetic transaminase levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(IU/liter)		
-1	49.00±2.20[a2]	42.40± 3.20[b]	49.60±6.74[a]	45.60± 6.82[a,c]
1	48.80±6.29[a]	45.60± 8.82[a]	38.50±9.06[a]	32.20± 4.61[a]
2	41.40±7.44[a]	35.80± 3.77[a,b]	43.20±9.51[a,c]	42.20±13.93[a,c]
4	44.10±6.61[a]	33.40±15.44[b,c]	39.50±5.68[a]	32.40±11.75[a,c]
8	39.80±5.51[a]	38.40± 4.50[a,b]	37.80±5.90[a,c]	33.40±16.97[a]
16	42.80±5.29[a]	47.70± 3.50[a,c]	45.00±8.00[a]	28.40±16.04[b]
20	37.30±3.43[a]	38.90± 1.73[b,c]	39.40±5.08[a]	30.90±16.64[b]
Combined $\overline{X}$	43.31±7.96	40.36± 8.50	41.86±8.06	35.01± 3.94

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 12. Mean alkaline phosphatase levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(IU/liter)		
-1	90.40±17.03[a2]	95.60±24.40[a]	106.00±21.55[a]	103.00±23.73[a]
1	108.00±22.28[a]	110.00±26.39[a,c]	71.40±15.97[a]	50.60± 7.34[b]
2	64.80±17.93[a]	67.00±11.55[a,c]	59.80±16.83[c]	47.30± 6.88[b]
4	110.30±29.30[a]	117.60±43.54[a]	90.50±24.11[a]	68.90±31.37[a]
8	122.20±24.03[a]	118.90±28.17[a]	105.60±25.00[a]	72.20±41.14[a]
16	114.80±20.72[a]	117.80±33.04[a,b]	96.30±13.17[a,c]	63.00±35.74[a,b]
20	130.10±25.83[a]	133.90±33.02[a]	111.50±20.26[a,b]	78.00±44.62[a]
Combined $\overline{X}$	105.80±29.82	107.01±34.87	91.60±26.34	69.00±34.13

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences (p≤0.05) between means.

Table 13. Mean sorbital dehydrogenase levels for groups of calves supplemented at different levels of iodine for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(IU/liter)		
-1	19.60±9.88[a2]	14.30± 4.37[b]	19.70±7.93[a]	16.30± 3.77[b]
1	9.70±3.18[a]	18.70±11.87[b,c]	13.40±2.11[b,c]	7.30± 1.06[b]
2	16.40±8.54[a]	12.90± 1.20[b]	17.10±8.48[a]	9.50± 5.46[a]
4	15.20±3.65[a]	15.00± 6.94[a]	16.80±5.63[a,b]	13.30± 7.70[b]
8	15.10±2.13[a]	16.30± 5.23[b]	16.70±5.58[b,c]	27.40±27.16[b]
16	18.10±3.81[a]	16.50± 5.13[a]	17.90±4.10[a]	13.00± 6.00[a]
20	19.70±2.58[a]	18.80± 3.12[a]	17.80±2.97[a]	13.00± 1.19[b]
Combined $\overline{X}$	16.31±6.19	15.93± 6.31	17.06±5.26	15.21± 6.14

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 14. Mean serum immunoglobulin (IgG) levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	3750± 397.9[a2]	3400± 966.1[b]	2430±1444.9[b]	2873± 971.0[b]
1	3230± 853.8[a]	3345± 506.3[a,b]	3110±1260.5[a]	2550± 773.5[a,b]
2	1695± 913.6[a]	1980± 812.1[a]	2520±1124.4[a]	2590±1516.2[a]
4	2710±1287.9[a]	2728±1732.0[a]	2850±1209.5[a]	3200±1229.3[a]
8	2640±1487.9[a]	1880± 922.0[a,b]	1800± 905.7[a,b]	1240± 748.6[b]
16	2405±1380.9[a]	1719±1316.8[a]	1650±1296.3[a]	987±1117.4[a]
20	2128±1617.4[a]	1646±1113.2[a]	1500± 956.7[a]	1911±1646.1[a]
Combined $\overline{X}$	2651±1313.3	2385±1279.0	2265±1273.3	2150±1370.1

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a,b]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 15. Mean serum immunoglobulin (IgM) levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Level of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	119± 46.67[a2]	129± 38.88[a]	95± 58.36[a]	81± 31.43[a]
1	134±100.13[a]	99± 61.55[a,b]	184± 47.73[b]	237±109.22[a]
2	130±122.96[a]	110±51.64[b]	225± 80.55[a]	176± 36.95[b]
4	150±100.25[a]	149± 85.64[a]	252±121.47[a]	173±129.21[a]
8	84± 51.68[a]	161±135.42[b]	169±122.70[b]	160±142.98[b]
16	103± 71.34[a]	80± 28.23[b]	198±124.25[a]	116± 98.50[a]
20	133± 82.98[a]	82± 53.45[a]	105± 54.01[a]	70± 60.92[a]
Combined $\overline{X}$	121.8±84.91	115.5±75.77	175.2±103.96	144.8±107.28

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a,b]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 16. Mean serum immunoglobulin (IgA) levels for groups of calves supplemented at different iodine levels for 6 months

Weeks on Experiment	Levels of Supplemental Iodine (mg/head/day)[1]			
	0	50	250	1250
		(mg/dl)		
-1	313± 69.19[a2]	307± 81.38[a,b]	289±145.48[b]	319±103.01[a,b]
1	359± 64.05[a]	358± 63.73[a]	398± 88.17[a]	426±112.41[a]
2	432± 87.03[a]	412±100.00[a]	382± 61.14[a]	378± 61.25[a]
4	410± 56.77[a]	374± 71.34[a,b]	374±123.87[b]	373±142.13[b]
8	317±121.73[a]	267±121.66[a]	242± 83.91[a]	262±139.35[a]
16	370±129.36[a]	297±114.24[a,c]	326± 36.73[b]	246±135.25[a]
20	219± 89.01[a]	230± 79.16[a]	258± 89.17[a]	183±138.17[a]
Combined $\overline{X}$	345.8±110.07	320.7±106.59	324.07±108.73	312.36±141.47

[1]As ethylenediamine dihydriodide (EDDI).

[2]Mean ± SD.

[a-c]Different letter superscripts at each time period indicate significant differences ($p \leq 0.05$) between means.

Table 17. Polybrominated biphenyl (PBB) levels for calves supplemented at different iodine levels for 6 months

Calf ID number	PBB in parts per million	Calf ID number	PBB in parts per million
Group I (controls)		Group III (250 mg)	
2	0	29	0
7	0	35	0
12	0	18	0
17	0	20	.011
38	0	25	0
39	0	26	0
21	0	1	0
27	0	13	0
31	0	15	0
32	0	16	0
Group II (50 mg)		Group IV (1250 mg)	
28	.011	34	.028
40	0	23	0
3	0	6	.003
4	0	11	0
5	0	19	0
36	0	22	0
8	0	24	0
9	0	30	.001
10	0	37	0
14	.003	33	0

oxalacetic transaminase, and hydroxybutyric dehydrogenase in Groups III and IV as compared to the controls.

Clinical Data

The recorded clinical signs seen in all animals during the trial period are presented in Appendix A and summarized in Table 18. Temperature elevations (above 103 F), appetite, and respiratory signs (coughing, nasal discharge, lacrimation) were observed daily during the trial period.

Calves in Group I showed very few clinical signs of illness throughout the trial period. Initially some calves had dermatomycosis ("ringworm"). However, this condition disappeared in 4 to 6 weeks. Temperature elevations were noted in several animals following vaccination with *Brucella* Strain 19 the first and third months of the trial. Also, some animals were "off feed."

Group II also had a few cases of dermatomycosis initially, but they recovered in 1 month. Three animals in Group II showed occasional respiratory symptoms: nasal discharge, lacrimation, and coughing. These signs occurred for 2 to 3 days each month for 3 months. No signs were seen the last 3 months of the trial. One animal developed gaseous bloat during the fifth month. The heifer was treated and recovered without any complications. As in Group I, temperature elevations occurred after brucellosis vaccination during the first and third months of the trial period.

Nearly all calves in Groups III and IV coughed and had profuse nasal and lacrimal discharges, rough hair coats, increased lung and tracheal sounds, elevated body temperature, skin lesions, and poor appetites (Figures 1, 2 and 3). Some animals also developed corneal

Table 18. Summary of clinical signs for groups of calves supplemented at different iodine levels for 6 months

Month	Off Feed	Respiratory Signs	Temp. Elevation
		Group I (controls)	
1	4	5	53
2	0	1	0
3	0	0	14
4	0	0	0
5	0	0	0
6	0	0	0
		Group II (50 mg)	
1	4	14	56
2	3	16	1
3	17	7	10
4	0	1	0
5	0	0	0
6	0	0	0
		Group III (250 mg)	
1	43	81	70
2	32	77	8
3	24	26	12
4	20	2	0
5	14	0	0
6	2	0	0
		Group IV (1250 mg)	
1	150	116	94
2	82	97	7
3	63	32	12
4	19	2	0
5	14	1	0
6	6	0	0

Figure 1. Calf in Group IV (1250 mg) with mucopurulent nasal discharge.

Figure 2. Calf in Group IV (1250 mg) with nasal discharge.

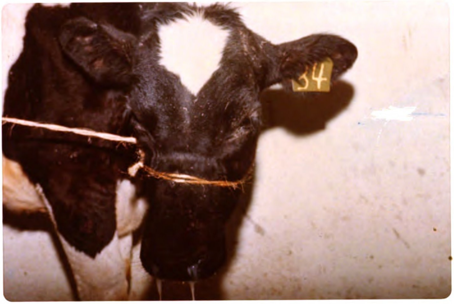

Figure 3. Calf in Group IV (1250 mg) which died of bronchopneumonia.

Figure 4. Skin lesion on calf in Group IV (1250 mg) with partial alopecia.

ulcers. The above clinical signs and symptoms in Groups III and IV were most prevalent the first 3 months of the trial. During the next 3 months, there was gradual remission of clinical signs and symptoms.

During the third month of the trial, skin lesions developed on animals in Groups III and IV (Figure 4). Two animals (1 in Group III and 1 in Group IV) were affected. Partial alopecia in the cervical region was the first sign observed. This extended to the dorsum of the back. The skin became thickened and wrinkled. Histopathological diagnosis made from skin biopsies of 3 animals in Group IV was mild eosinophilic dermatitis with some acanthosis. After the fifth month of the trial, skin lesions started to disappear and, at the end of the experiment, were nearly absent. Unknown allergic response seems the probable cause of this eosinophilic dermatitis.

Microbiology

Nasal swabs from animals showing respiratory symptoms produced moderate to heavy growths of *Pasteurella* sp. on culture media. Virus isolation tests were negative. Nasal cultures taken from clinically normal animals also produced *Pasteurella* sp. *Pasteurella* sp. are part of the normal flora of the bovine respiratory tract. It is a frequent secondary invader when the resistance of the animal is reduced by various stresses. Apparently, receiving excessive levels of iodine can result in a secondary *Pasteurella* pneumonia.

Lacrimal secretions from animals with keratoconjunctivitis and/or corneal ulcers produced a light to moderate growth of *Moraxella bovis* when cultured for bacteria.

Necropsy

Two of the 10 calves in Group IV died, 1 at 30 days and the other at 60 days after iodine dosing started. Before death, both animals developed severe dyspnea, open-mouth breathing, profuse nasal discharge, and greatly increased lung sounds. The postmortem finding was severe bronchopneumonia.

Necropsies were performed on all animals at the end of the trial period by pathologists in the Department of Pathology, Michigan State University, East Lansing, Michigan.

CONCLUSIONS

Clinical signs of iodine toxicity in dairy heifer calves are related primarily to the respiratory and integumentary systems. Increased lung and tracheal sounds, coughing, bronchopneumonia, partial alopecia, profuse nasal and lacrimal discharge, rough hair coats, and poor weight gains are associated with iodine toxicosis.

Calves supplemented with a high level of iodine had lower than normal (p-0.05) serum calcium, phosphorus, magnesium, sorbital dehydrogenase, hydroxybutyric dehydrogenase and glutamic oxalacetic transaminase levels. Also, this group of calves had lower red blood cell counts and hemoglobin values. No clinical signs of iodine toxicity were noted in animals fed 20 times the minimum daily requirement for 6 months.

The minimum toxic level of iodine toxicosis in dairy heifer calves seems to be near 200 to 250 mg daily. Calves may develop a tolerance to iodine and show remission of clinical signs.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Drew, B., and Williams, D. G.: The Effect of Excess Dietary Iodine on Pregnant Mares and Foals, The Veterinary Record, 1975, 97:93-95.

2. Elmer, J.: *Iodine Metabolism and Thyroid Function*, Oxford University Press, 1960, p. 274-286.

3. Fisher, K. D., and Carr, C. J.: *Iodine in Foods: Chemical Methodology and Sources of Iodine in the Human Diet,* Food and Drug Administration, Washington, D.C., 1974.

4. Hamilton, M. A., and Geever, F. F.: The Use of Potassium Iodide in Combination with Streptomycin in the Treatment of Experimental Tuberculosis in Guinea Pigs, Am. Rev. Tuber., 1952, p. 680-695.

5. Hillman, D., Bolenbaugh, D., and Convey, E. M.: Iodine Toxicity and Thyroid Disturbances in Dairy Cattle, Dept. of Dairy Science, Michigan State University, East Lansing, MI, 1976.

6. Kolmer, J. A., Matsunam, I., and Broadwell, S.: The Effect of KI on the Leutin Reaction, J. Am. Med. Assoc., 1961, 67:718-719.

7. Matovinovic, J.: Survey of Iodine Intake in Cattle in Michigan, 1975-1976: Effect of Excessive Iodine Intake on the Iodine Content of Milk and Possible Disorders of Thyroid Function of Cattle, Dept. of Internal Medicine, University of Michigan Medical School, Ann Arbor, MI, May 25, 1976.

8. McCauley, E. H., Linn, J. G., and Goodrich, R. D.: Experimentally Induced Iodine Toxicosis in Lambs, Am. J. Vet. Res., 1973, 34: 165-170.

9. McCauley, E. H., and Johnson, D. W.: Disease Problems in Cattle Associated with Rations Containing High Levels of Iodine, Bovine Practitioner, 1972, 7:22-27.

10. Miller, J. K., and Swanson, E. W.: Performance and Iodine Metabolism of Dairy Cattle with Iodine^{131} Injury, J. Dairy Sci., 1967, 52:95.

11. Miller, J. K., and Swanson, E. W.: Effects of Iodine^{131} Thyroid Damage on Lactation and Thyroid Function in the Bovine, J. Dairy Sci., 1969, 56:378-384.

12. Miller, J. K., and Swanson, E. W.: Metabolism of Ethylene-diamine Dihydro-Iodide and Sodium or Potassium Iodide by Dairy Cows, J. Dairy Sci., 1972, 56:378-384.

13. Miller, J. K., Swanson, E. W., Spalding, G. F., Lyke, W. A., and Hall, R. F.: The Role of the Abomasum in Recycling of Iodine in the Bovine, J. Dairy Sci., 1972, 47:539.

14. Newton, G. L., Barrick, E. R., Harvey, R. W., and Wise, M. B.: Iodine Toxicity: Physiological Effects of Elevated Dietary Iodine on Calves, J. Anim. Sci., 1974, 38:449-455.

15. Salter, W. T.: *Endocrine Function of Iodine,* Harvard University Press, 1940.

16. Stone, O. J., and Willis, J.: Iodide Enhancement of Inflammation Experiment with Clinical Correlation, Tex. Rep. Biol. Med., 1967, 25:205-213.

17. Wallace, C. E.: Iodine Toxicity in Cattle, Georgia Vet., 1975, 27(6):25.

18. Webster, S. H., Rice, M. E., Highman, B., and Oettigen, W. F.: Iodine, J. Pharm., 1957, 120:171.

19. Wohl, M., and Goodhart, R. S.: *Modern Nutrition in Health and Disease,* Lea and Febiger, p. 274-286, 1960.

20. Underwood, E. J.: *Trace Elements in Human and Animal Nutrition,* Academic Press, 1977.

APPENDIX

APPENDIX A

CLINICAL SUMMARY FOR GROUPS OF CALVES SUPPLEMENTED AT DIFFERENT IODINE LEVELS FOR 6 MONTHS

Key

C = coughing

L = lacrimation

ND = nasal discharge

BV = *Brucella* vaccination

T3+ = body temperature of 103 F

T4+ = body temperature of 104 F

T5+ = body temperature of 105 F

T6+ = body temperature of 106 F

F = feed not eaten (in grams)

R = rales

D = diarrhea

OF = "off feed"

S = skin lesions

Appendix A (continued)

Group I	September 26	27	28	29	30	Group II	September 26	27	28	29	30	Group III	September 26	27	28	29	30	Group IV	September 26	27	28	29	30
2					C	3					C	1					103 C	6	L	L			C
7						4						13						11					C
12					L	5						15			103.8° 104.8		105.2° -114gm	19					
17						8						16						22					103.8° C,ND -114gm
21						9						18						23					103° ate little
27						10					C	20						24					103.5° C,-114gm
31						14	C				C	25						30			C	OF	
32				C		28						26			C		C	33				OF	ND,C -114gm
38				103.1°		36					C	29	103°					34					C
39						40						35						37					C -114gm

Group I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	OCTOBER 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
2						BV T5+	T4+	T7+				T3+																		
7					T5+	BV T7+	T4+	T6+	T5+					T4+	P- 100															
12	L				T3+	BV	T4+	T5+ L	T3+		T3+	T3+ P- 253	T3+							S		L	L							
17	T3+				T3+	BV	T5+	T6+	T5+	T3+	T3+					T3+											T3+	T4+		
21						BV	T5+	T4+ OF	T3+										L											
27		ND				BV	T3+	T5+	T4+	T3+		T3+								S										
31						BV	T4+	T5+ OF	T4+																					
32						BV	T5+	T4+	T4+	T3+																	T3+			
38						BV T6+	T4+	T6+	T6+	T4+	T3+				ND					S										
39						BV T5+	T4+	T3+	T4+																					

Group II	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	OCTOBER 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3	L					BV,L T6+	T4+	T3+	T3+											S		ND								
4	L					BV	T4+	T4+	T4+																			P-34		
5	L					BV,L T3+ C	T4+	T5+	T4+	T3+									L,ND R,D											
8	L					BV	T6+	T5+	T5+	T3+	T3+	P- 859				T3+			T3+ R						T3+					
9						BV	T4+	T7+	T4+	T3+									T5+ R	T5+ S,R L,C										
10	L					BV,R T5+	T5+	T6+	T4+	T3+	T3+	T3+																		
14					T3+	BV,C T4+ R	T4+ R	T4+	T3+																			P-59		T3+
28						BV	T3+	T6+	T3+										ND,R D									P- 137		
36						BV,C T6+	T4+	T4+	T4+	T3+					T3+			T3+										T3+ P- 224		
40					T3+	BV	T4+	T3+	T4+	T3+	T3+																			

Appendix A (continued)

Group III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 OCTOBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	G	T3+	T3+	T3+ R		BV	ND T5+ OF	T5+ OF							T3+	F-35	F- 223													
13		R,D				BV	T5+ OF	T5+ OF	T4+	T3+					R			T4+ C,R L		L,S		L	L	L	L	L	L	L,F- 807		
15	T5+ R,ND OF,D	ND	T4+ OF	T4+ L,R OF	T4+	BV,R C,ND T4+ OF	T4+ ND,L C,D OF	T4+ OF	T4+ D,C ND,R L	T3+ ND	L,ND D,F- 381	F- 245, -96	T3+ R,ND L	F- 123, -422	D,ND L,R C,F- 205, 46	F- 112 L,D C	ND,D	ND F-94 C,R L,ND		ND F- 131	F-90 ND,C	ND	F-89 L		F- 136 ND,D R	F-93 ND,C	F-56 ND	F-38		ND,D
16				R,C		BV	T3+	T4+ OF	T4+	T3+					R											R				
18		R	L	L	T3+	BV OF	ND T5+ OF	T5+ OF	T3+ C	ND	T3+ F- 134	F- 107	ND,S		R,ND F-89 C	T3+ ND	C,ND	ND,C R			F-77	T4+ ND,L F-128	ND	T3+	F-28	R	ND	F- 245		
20		C			T3+	BV	ND T6+ OF	T5+ OF	T4+ C	T3+ ND	T3+	T4+				C				S								F- 263		
25						BV	T6+	T5+ OF	T5+	T3+ ND	T3+		ND					ND,L R		C										
26		R				BV	T4+ C	T6+	T4+	T5+	T4+	T3+	T3+						T3+			F-76			R,C					
29	T3+					BV	T4+	T4+	T4+	T4+ ND	T3+		T4+		T3+	T5+ R	T3+ ND	T3+ R,ND	T3+ R											C
35			OF ND T3+	ate little		BV OF	T4+ OF	T4+ OF	T4+	T3+		T3+	T3+ F- 113	F- 166	F- 352	F-66		ND,L R				F-77			R,C					

Group IV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 OCTOBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6	T3+	T3+ L,R	T4+	no feed	T4+	BV,C OF ND T3+	T6+ ND,C OF	T5+ OF	T4+ C,ND	T3+ ND	T4+ F- 426	T3+ F- 479, -208	T4+ C,ND F- 133	T4+ F- 186, -341	ND F- 140, -181	F- 247, -54 C	F- 330, -560 C	F-88 ND,L F- 127 C,R	F- 356	C,F- 204	F- 57, -97	L,F- 311	F- 175, -174		F- 225, -364 R,C	F- 732 T6+ C,R	F- 298, -383	F- 249	F- 115	T4+ C F- 538, -390
11		C	ND		T3+	BV OF	OF,C	T3+ OF	T6+ ND	T3+ ND	T3+ F- 568	F- 341	F-57		R F-43	F-34 T4+	C	F-47 C,ND L,R			F- 198	L,ND F-30		L	R,C L	L	L	L	L	
19		ND,C		ate little	T4+	BV OF C,ND T5+	OF,C T5+	T5+ OF		T4+ ND	T3+ F- 808	T4+ F- 787, -413	T4+ C,R ND F- 730	F- 510, -857	F- 725, -930	F- 747, -828 T3+ C	D,R F- 795, -908	down D,ND C,R L,no feed T98°	no feed D,up R	no am feed F- 510	C	R,C down	dead							
22	C,OF ~225 gm		no feed T3+ ND	ate most	T3+ ND	BV,R ND,C T3+	ND T3+	T5+ OF	T5+ C,ND	T3+	T3+ ND,C F- 155	T3+ F- 254, -105		F-89	F-46		F- 179	T3+ ND F-50	F-60	C,S				F- 201	F- 239					
23	C,R OF -454 gm	T3+ ND,C	no feed	no feed	T3+	BV,L ND	ND,L T4+ OF	T5+ OF	T5+	T3+ ND	T3+ F- 371	T3+ F- 121	T3+ F- 318 C	F- 181, -258	F- 405, -154	F- 284, -71	F- 157, -246	ND,L F- 405 R F- 129	F- 439, -219	C,S F- 285, -281	F- 57, -435	ND OF	F- 229		F-81 C	F-76	F- 28, -23 ND	F- 808	F-87	
24	T3+ ND OF ~225 gm	ND	no feed T3+ ND,L	L ate most	T3+	BV,R	T5+	T5+ OF	T4+	T4+	T3+ F- 146		T3+ R F- 158		ND,R		ND	T3+ ND,C F- 108	T3+	S,F- 228		F- 163	F- 99, -86	F- 266				T-56		
30	OF (none)	OF	no feed	ate most	ate lit- tle	BV OF	OF	T4+ OF	T4+	T6+ ND	T5+ S,L F- 832	T4+ S F- 623, -97	T6+ L,S F- 317, -260	T3+ F- 223	T5+ L,C R F- 130	F- 92, -262 L T3+	T4+ ND,R F- 130	T5+ L F- 290		L F- 224	F- 274	L	F- 70, -82 L	L F-91	F- 334, -83 L	L	ND,L	L F-51	L	

Appendix A (continued)

Group IV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 OCTOBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
33	OF (none) T3+	T4+ L,C R,OF	no feed T3+ C,L	L,C no feed	T4+ ate lit- tle	BV OF	T4+ OF	T4+ OF	T4+	T3+ ND	F- 497	T3+ F- 246	F- 113, -119 ND,C	T3+ F- 386, -66	R F- 95, -206	F- 191, -154	F- 358, -547	F- 143, -119 C,R	F- 558	ND,S F- 57, -264	F- 201, -488	F- 199, -437	F- 186, -387	F- 382	F- 195, -180	F-91	F- 157, -159	F- 114	F- 104	
34	OF (none)	L,OF	no feed C	ate most	ate lit- tle	BV OF	T3+ OF	T5+ OF	T5+	T3+	F- 356	F-74	ND,C																	
37	T3+ OF (most)	T3+ L,R D	no feed T4+ L	C,L	T3+ L	BV,R C	T6+ C	T5+ OF	T4+	T4+ ND	T4+ F- 450	T4+ F- 61, -135	C		T3+ L,C R	L		ND,L R,F- 76		L		L,ND	L	L	R,C L	ND,L	L	L	L	

Group I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 NOVEMBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
2																														
7																														
12																														
17																														
21																														
27																														
31																														
32																														
38																														
39																											ND			

Group II	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 NOVEMBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3								ND							ND	T3+				C		ND							ND	
4													F-143									ND								
5	F- 567	ND F-560																							C		C			
8							C																							
9	T3+																					C	ND		ND				ND	
10																						ND			C					
14								ND								-56														
28																														
36																														
40																														

Group III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 NOVEMBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1		F- 18, -361	T4+ F- 84, -198	F- 248, -127 T3+						F-96	ND									ND		ND					C		ND	
13	L	ND,L C	ND,L	T3+	L	L	L	L			ND								ND	ND		ND			ND					
15	ND F- 120, -289	ND,C F- 599, -595	ND T3+ F- 579	F- 70, -517 ND	ND F- 276	ND F- 155	C,ND F- 282	ND,L F-96	F- 243 ND F-170	ND,D F- 110	ND	ND F- 109		F- 106, -237	F-73 ND	C,ND		-442	ND,S	ND -176		ND	-63 ND	-129	ND,C	-94	C,ND	D,ND	-104 ND	
16											ND								ND				ND						ND	
18		F-88					ND		ND	ND	C,ND				ND	ND			ND	ND		ND			ND			C	ND	
20									F- 867	ND	ND				ND					ND,C					ND				ND	
25	F- 153	F-74					C																							
26			T4+ F-183				C																		ND					
29				T4+		T3+													ND						ND				ND,C	
35	F-68	F-42	T3+ F-331		F- 129	F- 307	C		F-327							ND													ND	

Appendix A (continued)

Group IV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NOVEMBER 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6	F- 464, -459	F- 437, -397	T3+ F- 544, -435	F- 383, -125	T3+ F- 739	F- 330, -190	C,ND F- 180, -459	ND,C F- 469, -291	S,F- 329, -243	F- 158, -111 C	ND,D F- 76, -357	D,F- 484	F- 226	F- 352, -310	F- 252, -200 ND,C	C -129 -391	-142 -296	-354	-196 -63 C,ND	S -190	-96	S	S	-249	C			C,ND -281 -189	ND,S -356	-174 -163
11	L	L	L	ND	ND,L	ND,L	ND,L	L,C ND		ND,C					C	ND			C,ND			ND,C	ND,C		ND,C			C	ND	
19																														
22			ND,C T4+ F-201	ND	ND,C	ND	ND	ND,C	S		ND					ND			ND,S C	ND,S		ND,S	ND,S C			-626	T3+		ND,S	
23	F-66	F- 138, -202	T4+ F-306		C			ND,C	S		ND				C	ND			C				-70 ND					C,ND	ND,S	
24	F- 534		T4+ F- 87, -148	F-50 ND	C	ND		C	S							ND			ND	C		ND			ND	-160			-68 ND,C	-107
30	F- 85, -547 L	F- 136, -161 L	F- 345, -132 L	F- 102 ND	ND,L F-50	F- 196, -274 L	L,ND F- 399	C,L F- 359	S,F- 327, -216	F- 270 ND,C	F-102		F-95	F- 304	F- 162	-271 -122	-134 -115	-419	ND -265 -415	ND,S -226	-122	ND,S -82	ND,S -42	-79 -110	-218	-374	-177	D,C ND -140 -121	-249 -148 ND,S	-380
33	F- 284	F- 133	T3+ F- 104	ND	ND	F- 222			S,ND	F-41	F-88, -57		F-104		ND F-66	ND,C -116	-72 -123	-125	-196 -180 C	ND,S	-58	ND,S -204	-35 -204 S	-35 ND,S C		-147	-345		-143	
34	F- 512	F-44	F- 218	F- 102, -47	ND F- 222	F- 43, -192	C		S						C,ND				S	ND,S		S -62	-319 S,C			-694		C,ND	ND,S	
37	L	L	L		L	L	L	L,C			F-51				C				-30											

Group I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	DECEMBER 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
2															T5+															
7															T5+															
12															T6+		T3+													
17															T5+		T4+													
21															T6+		T3+													
27															T5+															
31															T4+															
32															T5+															
38															T6+		T4+													
39															T4+															

Group II	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	DECEMBER 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3															T6+ -593	L -688	L	L	L	L										
4															T5+ C															
5															T4+															
8														-826	T4+			-801												
9														-379	T6+ ND,C -639 -626	-165														
10															T5+															
14														-416	T5+ -832	-472														
28															T5+															
36														-290	T4+ -386	-997	-147 T3+	-143	-225			-58			-756					
40															T6+															

Appendix A (continued)

Group III	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 (DECEMBER)	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1		ND												-525	ND T4+ -325	-484	-67 T3+													
13															T5+ ND		-539													
15	ND,L	ND -93			-171	-115	-228	ND,S	ND	-246			-113	ND,L S -212 -81	ND,C T5+ -394 -211	-1156	-329	-230	-76	ND		-289 -189			-222 C					
16	ND														T3+ C															
8															ND,L T4+															
20	ND	ND													ND T5+ -90	-320														
25															T6+	-1017	T3+													
26				-134											C T5+															
29															T5+															
35	ND														T5+ ND	-523														

Group IV	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 (DECEMBER)	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6	ND,S C, -75 -145				-57	-213	-298 -124	S,C			-55	-63		ND,S -320 -380	-480 -427 T5+ C,L,S	-950	-276 T3+			S	C,S	-109 -108								-117
11								S	C					S	T3+ S	-762	-423 T3+				S									
19																														
22	S	ND												S	ND,L S T5+	-1157				S	S									
23					-161				ND						T5+ L	-799	-399 -199 T4+	-93	-204	-183	C,S -166	-652					-113			
24	ND	ND -536			-257			S	ND						C,ND T6+ L,S	L -502	-311 L	L -92	L	L	C,S -114	-373 -113			-129		-110		-95	
30	-170 -56	-404	-473 -251	-353 -276	-317	-475	-611 -369	-157 -203		-295 -157	-187 -440	S,L		S -167	T5+ L,C -244	-889	-253			S	S		-188							-300
33	C	ND -102	-124	-88	-42		-150	S,C ND						S -413 -235	-87 -153 L,S T4+ ND,C	-544	-238 T3+			S,C	S	-210 -186			-264					
34	S	ND	-64	-36	-169	-630 -768	-836 -806	no feed ND,S L,R	down ND,C died																					
37															T5+,L		T3+				S									

Appendix A (continued)

Group II	JANUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
3						R,D																									
4																															
5																															
8																															
9																															
10																															
14																															
28																															
36																															
40																															

Group III	JANUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1																															
13																															
15				-198	-97	-58			C	-95	-54		-105	-120			-148	-104	-219	-140 -199	-333		-153 -278	-126	-163			-404	-481	-330	
16														ND																-60	
18																						-147									
20																														-70	
25																															
26																															
29				*																											
35																															

Group IV	JANUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
6																															
11																															
19																															
22														-389							-166	-195	-420		-252						
23																															
24														-162 -208					-196	-175	-161				-259	-262		-198	-347		
30									-48,C											-106								-128			
33									-43										-134		-438										
34																															
37									C																						

Group II	FEBRUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	skin cond. improved																											
13	*																											
15	* -183 -302					-278	-554	-167	-135		-216	-189	-204						-144		-105	-162				-118	-154	
16	*																											
18	*																								-183			
20	*																											
25	*																											
26	*																											
29	*																											
35	*																											

Group IV	FEBRUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
6	skin cond. improved						-514		C,ND		-287		-67															
11	*																											
19																												
22	*																											
23	* -258																											

Appendix A (continued)

Group IV	FEBRUARY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
24 *	-415 -131					-126	-146					-164																
30 *							-477				-378		-126															
33 *											-628	-119	-143															
34																												
37 *																												

Group III	MARCH 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1																															
13																															
15							-79							-104																	
16																															
18																															
20																															
25																															
26																															
29																															
35																															

Group IV	MARCH 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
6																															
11																															
19																															
22	-288		-288				-96												-217												
23																															
24							-183																								
30																															
33							-280																								
34																															
37																															