# Equine Glucose Tolerance

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# EQUINE GLUCOSE TOLERANCE [1]

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SEVERAL investigators have used the intravenous glucose tolerance test to study glucose utilization in domestic animals. In this respect, the term glucose utilization is defined as the rate of removal of injected or exogenous glucose from the blood (Hlad, Elrick and Witten, 1956; Reid, 1958). There is general agreement that the rate of removal of injected glucose by tissues of nonruminants is faster than by tissues of ruminants. However, apparently no reports on glucose utilization by the horse have appeared in the literature. The purpose of this investigation was to study the kinetics of equine glucose utilization using the intravenous glucose tolerance test procedure.

## Experimental Procedure

Two ponies, a 3-year-old stallion weighing 180 kg and a 2½-year-old gelding weighing 150 kg, were used for this research. They were housed on concrete in box stalls with free access to small outside runs and fed a ration of mixed hay, trace-mineralized salt, and water free-choice except as otherwise noted.

The intravenous glucose tolerance test procedure was similar to that used by other investigators. After inserting indwelling catheters into the left jugular vein, the ponies were fasted between 24 and 36 hr. prior to the the actual test. After collecting a zero time sample, a glucose solution (50% w/v) was injected and subsequent blood samples taken at 5, 15, 30, 60 and 90 minutes. The glucose load given pony 1 was equivalent to either 0.12 or 0.20 $g/W_{kg}^{.75}$ and that given pony 2 was equivalent to either 0.14 or 0.20 $g/W_{kg}^{.75}$. Each dose was replicated three times on the respective pony with a 3-day minimum lapse between replicates. Care was taken to insure that the ponies were not disturbed or subjected to abnormal environmental stress during the tolerance tests.

Blood samples were collected via an 18 gauge x 10 cm indwelling teflon catheter [3] in order to minimize the effect of psychosomatic stress on the plasma glucose concentration that might be caused from sampling by venipuncture. Samples were collected directly into evacuated glass tubes [4] of approximately 7 ml draw containing potassium oxalate (2.0 mg/ml blood) to prevent coagulation and sodium fluoride (2.5 mg/ml blood) to inhibit glycolysis (Annison and White, 1961; Somogyi, 1948). After centrifuging whole blood at 5,000 *g* for 10 min, plasma was decanted and frozen until analysis. Plasma glucose was measured enzymatically by the glucose oxidase procedure of Huggett and Nixon (1957) using a commercial enzyme preparation.[5]

## Results and Discussion

The intravenous glucose tolerance test results are presented in table 1. The marked post-injection hyperglycemia and the subsequent exponential decline of the plasma glucose concentration toward the fasting value is characteristic of glucose tolerance test results in other species (Amatuzio *et al.*, 1953; Banerji and Reid, 1934; Cook, Dye and McCandless, 1948; Davidson and Blackwell, 1967; Duncan *et al.*, 1956; Hlad *et al.*, 1956; Jarrett and Potter, 1952; Reid, 1958; Tunbridge and Allibone, 1940; Wakeman and Morrell, 1931). The glucose half-lives and utilization rates (calculated according to Reid, 1958) are given in table 2. Although the glucose half-lives appeared to increase as dosage increased, the difference was not statisically significant. The mean glucose half-life was 36 minutes. Thus, the mean glucose half-life in ponies appears to be longer than in man (19 min—calculated from data of Duncan, 1956) but shorter than in adult ruminants (140 min—calculated from data of Reid, 1958).

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[3] Longdwel catheter, Becton, Dickinson & Co., Rutherford, New Jersey.
[4] Vacutainers, Becton, Dickinson & Co.. Rutherford, New Jersey.
[5] Glucostat, Worthington Biochem Corp., Freehold, New Jersey.

TABLE 1. INTRAVENOUS GLUCOSE TOLERANCE TEST RESULTS

| | Pony 1 | | | | Pony 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.12[a] | | 0.20 | | 0.14 | | 0.20 | |
| Time[b] | Mean[c] | S.E.[d] | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| 0 | 79.0 | 5.19 | 84.3 | 5.36 | 75.3 | 9.02 | 82.3 | 4.33 |
| 5 | 130.3 | 30.99 | 158.3 | 17.95 | 173.3 | 22.55 | 146.7 | 6.33 |
| 15 | 91.7 | 5.23 | 132.0 | 14.00 | 100.3 | 9.49 | 129.3 | 7.84 |
| 30 | 89.3 | 6.06 | 119.7 | 15.96 | 98.3 | 5.23 | 118.7 | 7.69 |
| 60 | 88.3 | 2.66 | 112.3 | 8.66 | 85.0 | 5.99 | 105.0 | 6.92 |
| 90 | 82.7 | 4.63 | 99.7 | 9.61 | 83.7 | 4.97 | 99.7 | 8.29 |

[a] Glucose load in grams/$W_{kg}^{.75}$.
[b] Time post-injection in minutes.
[c] Plasma glucose concentration in milligrams per 100 ml.
[d] Standard error.

TABLE 2. MEAN GLUCOSE HALF-LIVES AND UTILIZATION RATES

| Parameter | Pony 1 | | Pony 2 | |
|---|---|---|---|---|
| | 0.12[a] | 0.20 | 0.14 | 0.20 |
| t[b] | 28 | 42 | 27 | 46 |
| k[c] | 0.026 | 0.014 | 0.025 | 0.015 |

[a] Glucose load in grams/$W_{kg}^{.75}$.
[b] Mean glucose half-life in minutes.
[c] Fractional removal rate of glucose excess per minute.

The glucose utilization rate (k), which is defined as the fraction of the glucose excess removed per minute (Reid, 1958), appeared to decrease as the glucose load administered increased, but this difference was not statistically significant. Thus, the conclusion, based on these results, that the glucose utilization rate in ponies is independent of the size of the glucose load administered is consistent with findings in other species (Amatuzio *et al.*, 1953; Hlad *et al.*, 1956; Reid, 1958).

Although comparisons of results between laboratories is made difficult by possible differences in experimental procedures and in the nutritional and physiological state of the experimental animals, a species comparison of tolerance times is presented in table 3. The term tolerance time has been defined as the time required for the elevated plasma glucose concentration to return to the pre-injection level (McCandless and Dye, 1950). In the case of ponies, tolerance times were obtained by extrapolation and ranged from 1.5 to 3.5 hr. with a mean of 3.0 hours. Therefore, according to the comparison in table 3, and assuming that tolerance times are indicative of utilization rates, glucose utilization in ponies is slower than in man, monkeys, rabbits, lambs and calves, but faster than in sheep.

A species comparison of increment indices is shown in table 4. The increment index is defined as the percentage of the plasma glucose excess removed per minute (Reid, 1958). The mean increment index in ponies was $2.0 \pm 0.38\%$ per minute and appears to be intermediate between man and sheep.

Although it is now generally accepted that the only theoretically acceptable method for measuring utilization rates is by continuous isotope infusion under steady-state conditions (Annison and White, 1961), the intravenous glucose tolerance test can give useful information on relative utilization rates, i.e., within species or between species.

Difference in relative sensitivity to insulin is a possible explanation of species dependent glucose utilization rates. It is generally considered that ruminants are less sensitive to

TABLE 3. SPECIES COMPARISON OF TOLERANCE TIMES

| Specie | Tolerance time, hr. | Reference |
|---|---|---|
| man | 1.0 | Tunbridge and Allibone, 1940. |
| monkey | 1.5 | Wakeman and Morrell, 1931. |
| rabbit | 1.5 | Banerji and Reid, 1934. |
| lamb | 1.5 | Jarrett and Potter, 1952. |
| calf | 1–2 | Cook *et al.*, 1948. |
| horse | 3.0 | this paper |
| sheep | 3–5 | Jarret and Potter, 1952. |

TABLE 4. SPECIES COMPARISON OF INCREMENT INDICES

| Specie | Increment index[a] | Reference |
|---|---|---|
| man (normal) | 3.7 | Duncan, 1956. |
| man (normal) | 3.0 | Hlad *et al.*, 1956. |
| man (mild diabetic) | 1.8 | Amatuzio et al., 1953. |
| man (severe diabetic) | 1.1 | Amatuzio et al., 1953. |
| horse | 2.0 | this paper |
| sheep | 0.5 | Reid, 1958. |

[a] Percent glucose excess removed per minute.

insulin than nonruminants (Annison and White, 1961). Thus, the horse may be intermediate with respect to insulin sensitivity. Another related possibility involves the available supply of endogenous insulin and, in particular, the possibility of differential insulin secretion rates following glucose administration. Recently, an increased insulin output has been demonstrated in dogs (Rappaport *et al.*, 1968) and humans (Levine, Streeten and Doisy, 1968) following intravenous glucose administration. The slower glucose utilization rate in horses compared to man and dogs could, therefore, result from a slower rate of insulin release or production.

The recent results of Hetenyi and Wrenshall (1968) suggest that animal variability might be influenced by differential adaptation of glucose turnover to exogenous glucose administration. These workers showed in normal dogs that changes in glucose disappearance rates were significantly correlated with changes in infusion rates. Further, this change was related to a decrease in the endogenous (hepatic) glucose production.

## Summary

The intravenous glucose tolerance test was used to study the kinetics of equine glucose utilization. Comparison of glucose half-lives, utilization rates, tolerance times and increment indices in ponies with these parameters in other species indicated that the removal rate of exogenous glucose from the blood of ponies is slower than in nonruminants, such as man, but faster than in adult ruminants, such as sheep.

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