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Error reporting in a large animal veterinary teaching hospital identifies medication errors occur most often in the prescribing phase of therapy

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OBJECTIVE
To identify the rate at which medication errors occurred over a 2-year period in a large animal veterinary teaching hospital and describe the types of errors that occurred.

SAMPLE
226 medication errors over 6,155 large animal visits occurred during the study period. Multiple errors may have affected the same patient.

METHODS
Medication error reports from March 1, 2021, to March 31, 2023, were reviewed retrospectively and classified by species, type of drug, and month and day of the week the error occurred. Errors were categorized according to multiple previously developed systems to allow for comparison to other studies.

RESULTS
226 medication errors occurred over 6,155 patient visits in a 2-year period: 57.5% (130/226) were identified by a dedicated large animal pharmacist, and 64.2% (145/226) of errors were identified and corrected before reaching the patient. Prescription/medication order errors (58.4% [132/226]) occurred significantly more often than errors in medication preparation (21.7% [49/226]; $P < .001$) and administration (19.6%; $P < .001$). Antibiotics (48.7% [110/226]) and NSAIDs (17.7% [40/226]) were the drug classes most involved in errors.

CLINICAL RELEVANCE
Most medication errors in this study occurred in the ordering/prescribing phase. This is similar to reports in human medicine, where standardized medication error reporting strategies exist. Developing and applying similar strategies in veterinary medicine may improve patient safety and outcome.

Keywords: medication errors, error reporting, decentralized pharmacist, medical error, large animal

A medication error is defined as “any error in prescribing, dispensing, or administration of medication. A medication error may or may not result in patient harm but is considered preventable.”[1,2] Since the release of the report *To Err is Human: Building a Safer Health System* by the Institute of Medicine in 2000, there has been immense focus on medication errors within human medicine and the effect of reporting on reducing these errors.[1] Rates of medication errors in human hospitals range from 0.78 to 1,400 errors/1,000 visits.[3,4] Despite the large volume of data available on medication errors in human medicine, identification of true rates at which errors occur is challenging due to a lack of standardized reporting and classification of errors.[4]

There is a stark difference in the volume of literature available regarding medication errors between human and veterinary medicine. In human medicine, a plethora of data describe rates and classification of medication errors and the ways in which error reporting can improve patient safety.[3–6] In veterinary medicine, there is a paucity of data describing error rates

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and many of the publications on the subject are editorials or studies focusing more on the second patient effect and less on the specific details of the errors.[7–13] Only 3 studies report rates and types of medical errors within veterinary hospitals, and only 1 study describes errors in large animal practice.[7,11,14] No studies to date have focused solely on errors associated with medications in large animal practice.

The objectives of this study were to describe the frequency and types of medication errors that occurred over a 2-year period in a large animal veterinary teaching hospital. We hypothesized that medication error rates in our large animal hospital would be similar to published rates in human medicine and 1 previous study in veterinary medicine and that our data would allow for identification of specific types of errors.

Methods

In March of 2021, a committee consisting of 2 clinicians, a large animal pharmacist, 2 veterinary technicians, and 2 members of hospital administration was developed within the Equine and Food Animal Veterinary Center of the North Carolina State University Veterinary Hospital. The purpose of this committee was to document, monitor, and reduce the occurrence of medication errors within the large animal hospital after multiple medication errors occurred that led to significant financial write-offs for diagnostics and treatments that occurred as a consequence. After the formation of this committee, a dedicated large animal pharmacist began attending daily rounds Monday through Friday to inspect patient treatment sheets and inpatient medication orders. Simultaneously, a renewed effort to encourage reporting of medication errors using a hospital-wide reporting system (including the small animal hospital) was carried out. Medication errors after the formation of the committee were reported either directly to the hospital-wide system or to the large animal pharmacist who then submitted the official report to the hospital system. From March 1, 2021, to March 31, 2023, errors were recorded in real time and evaluated retrospectively for the purpose of this study. Each error was classified as an individual event; thus, some patients had more than 1 error. The number of patient visits (defined as 1 visit/hospital stay) to the hospital for each month from which data were collected was also recorded.

All reported errors during this period were classified by the species in which they occurred, day of the week and month the errors occurred, and type of drug. Each error was also classified according to multiple classification schemes used in other studies.[1,7,15]

First, errors were classified by the phase of therapy in which the error occurred (**Supplementary Table S1**; prescription error, preparation error, administration error). Prescription errors were those that occurred during the placement of medication orders to pharmacy or when orders were incorrect on a patient's treatment sheet. Preparation errors were those that occurred after the prescription phase and included medications that were reconstituted or stored incorrectly or had incorrect doses or drugs prepared. Errors were classified as administration errors when the drug was ordered and prepared correctly but given incorrectly (eg, at the incorrect time, via the wrong route, to the incorrect patient).

The second classification scheme was that used by Wallis et al[7] and defined errors on the basis of the level of patient involvement (**Supplementary Table S2**; near miss, harmless hit, adverse event, unsafe condition). A "near miss" described an error that did not ultimately reach the patient but would have caused harm if it had; for example, if an injectable medication was reconstituted incorrectly but someone identified the error and corrected it before it was administered to the patient. An unsafe condition described circumstances or conditions that increased the probability of a patient safety event but were identified and corrected before they had the chance to reach the patient, such as an incorrect weight in a patient's record that was identified and corrected before drug orders were placed. Errors defined as harmless hits were errors that did reach the patient but did not cause any harm, such as a double dose of a medication being administered to a patient that showed no adverse effects after the error. Adverse incidents were errors that reached the patient and caused harm, such as a double dose of an aminoglycoside that was followed by azotemia.

Finally, we modified the 5 Rights (5 R's) of medication administration developed by Kron et al[15] to classify errors in administration (**Supplementary Table S3**; wrong drug, wrong time, wrong dose, wrong route, wrong patient, dose missed completely). Instead of the right drug, right time, right dose, right route, and right patient, we classified errors on the basis of whether they involved administration of the wrong drug, at the wrong dose, at the wrong time, via the wrong route, to the wrong patient, or missed entirely.

If errors took place in multiple steps of the process, the errors were classified by the first error that took place. For the phase of therapy and modified 5 R's scheme, errors were classified as they would have been if they had reached the patient. For example, if an oral medication was prescribed and prepared correctly, yet an individual nearly gave it via the IV route but was stopped before the error occurred, it would have been classified as an error that did not reach the patient, a near miss, an administration error, and a wrong route error.

Statistical analysis

Statistical analyses were performed using R software (version 4.2.3; The R Project for Statistical Computing), and significance was set at $P < .05$.[16,17] P values in the statistical tests are not adjusted for multiple testing across analyses, only within individual analyses when post hoc tests are performed; these results are considered exploratory. The type of post hoc adjustment depends on the analysis. χ^2 goodness-of-fit tests were used to compare difference in proportions of errors by major type, the 5 Wrongs, and the day of the week. These analyses were performed on (1) all medication errors and (2) the subset of medication errors that reached the patient. When significant, post hoc pairwise comparisons using false discovery rate–adjusted exact multinomial tests were then performed to identify which types of errors or days of errors were more or less common than others. Also when significant, additional analyses (which were either χ^2 tests of independence or Fisher exact tests) were used to determine whether these distributions were significantly different between errors that did and did not reach the patient.

Additionally, trends over time were analyzed across (1) individual months, (2) categorical month of the year, and (3) months treated as continuous time. Individual months were analyzed with a χ^2 goodness-of-fit test, assuming errors in each month should be proportional to number of accessions. This was not done separately for the subset of medication errors that reached the patient due to small sample sizes in each month. Categorical month (ie, January, February, March, etc) was analyzed using negative binomial regression analysis with the natural logged number of accessions divided by 1,000 as an offset; these analyses were performed on (1) all medication errors and (2) the subset of medication errors that reached the patient. When significant, post hoc pairwise comparisons were run using the Tukey adjustment for family-wise error rates.

Results

Two hundred twenty-six errors were reported from March 1, 2021, to March 30, 2023. During this period, there were 6,155 patient visits, with a median of 241 (range, 188 to 333) patient visits/month Of the 6,155 patient visits, 4,935 (80.2%) patients were equine and 1,220 (19.8%) were food animal (primarily small ruminants and camelids, with occasional cattle and pigs). The total error rate over the study period was 36.8 errors/1,000 patient visits. For most errors, the individual who identified the error was recorded. Errors were most identified by the large animal pharmacist (130/226 [57.5%]), followed by other personnel (82/226 [36.3%]). The individual that identified the error was unknown in 14 instances (14/226 [6.2%]). The majority of errors occurred in equid species (199/226 [88%]; **Supplementary Table S4**), and 64.2% (145/226) of errors did not reach the patients.

When classified by the impact on the patient **(Table 1)**, errors resulting in unsafe conditions were the most common (90/226 [39.8%]), followed by harmless hits (75/226 [33.2%]) and near misses (54/226 [23.9%]). The most common major error type was in the prescribing phase of therapy (treatment sheet or medication order errors; 132/226 [58.4%]), followed by administration errors (44/226 [19.5%]) and preparation errors (49/226 [21.7%]). Errors were significantly more likely to occur in the prescribing phase than during medication administration (P < .001) and medication preparation (P < .001). When errors were classified by the modified 5 R's scheme, the most common types were "wrong dose" errors (84/226 [37.2%]), followed by "wrong time" errors (63/226 [27.9%]) and "wrong drug" errors (24/226 [10.6%]). "Wrong dose" and "wrong time" errors occurred significantly more often than all other error types (P < .001 for all comparisons), and "wrong drug" errors occurred significantly more frequently than "wrong patient" errors (P = .003). The most common specific error subtype overall involved incorrect frequencies in prescriptions and medication orders (46/226 [20.4%]; **Supplementary Table S5**).

Antibiotics were the most common class of medication involved in errors (110/226 [48.7%]), followed

Table 1—Summary of 226 medication errors classified by error type that occurred over a 25-month period. Columns depict all errors (n = 226) and only errors that reached the patient (81).

	All errors (n = 226)	Errors that reached patient (n = 81)
Major error type		
Unknown	1 (0.4%)	0 (0%)
Prescription error	132 (58.4%)	30 (37.0%)
Administration error	44 (19.5%)	38 (46.9%)
Preparation error	49 (21.7%)	13 (16.1%)
Errors by impact on patient		
Unknown	0 (0%)	0 (0%)
Near miss	54 (23.9%)	0 (0%)
Harmless hit	75 (33.2%)	74 (91.4%)
Adverse incident	7 (3.1%)	7 (8.6%)
Unsafe condition	90 (39.8%)	0 (0%)
5 Wrongs (modified from 5 Rights scheme)		
Unknown	5 (2.2%)	0 (0%)
Wrong patient (1)	6 (2.7%)	4 (4.9%)
Wrong dose (2)	84 (37.2%)	27 (33.3%)
Wrong route (3)	14 (6.2%)	3 (3.7%)
Wrong time (4)	63 (27.9%)	29 (35.8%)
Wrong drug (5)	24 (10.6%)	11 (13.6%)
Dose missed completely (6)	15 (6.6%)	7 (8.6%)
Other	15 (6.6%)	0 (0%)

Data are reported as number and percent of total.

by NSAIDs (40/226 [17.7%]; **Supplementary Table S6**). Reported errors occurred most frequently on Tuesdays (48/226 [21.2%]), followed by Wednesdays (45/226 [19.9%]), Mondays or Fridays (each 41/226 [18.1%]), and Thursdays (30/226 [13.3%]), though these were not significantly different from one another **(Table 2)**. Reported errors occurred significantly less frequently on Saturdays (7/226 [3.1%]; $P < .001$ for all weekdays) and Sundays (12/226 [5.3%]; $P < .001$ for all weekdays except Thursday, with $P = .011$) than other days of the week. When error rates were compared by month, errors occurred most frequently in July (15.14 errors/1,000 patient visits), August (12.69 errors/1,000 patient visits), and June (11.14 errors/1,000 patient visits), and there was a statistically significant difference between months ($P = .04$), though there was no significant difference between months following additional post hoc analysis and Tukey adjustment of pair-wise comparisons. When each of the 25 months were compared as individual time points, significantly fewer errors were reported in May of 2021 than many other months (April, June, July, August, and September of 2021; March to October and December of 2022; and February and March of 2023). Significantly fewer errors also occurred in October of 2021 when compared to August of 2021 ($P = .030$), July of 2022 ($P = .006$), and February of 2023 ($P = .044$). Significantly more errors occurred in July of 2022 than in March of 2021 ($P = .016$), May of 2021 ($P < .001$), and October of 2021 ($P = .006$).

Eighty-one errors reached the patient (81/226 [35.8%]), giving a rate of 13.2 errors that reached the patient/1,000 patient visits. No medication errors resulted in death. Most errors that reached the patient occurred in equid species (75/81 [92.6%]; Supplementary Table S4). Antibiotics were the most common class of medication involved in errors that reached the patient (40/81 [49.4%]), followed by NSAIDs (14/81 [17.3%]; Supplementary Table S6). When classified by the impact on the patient, errors that reached the patient were classified as either harmless hits (74/81 [91.4%]) or adverse incidents (7/81 [8.6%]; Table 1). Administration errors (38/81; [46.9%]) and prescribing errors (30/81 [37.0%]) were the most common error type to reach the patient, though they did not occur at a significantly different frequency from one another ($P = .396$). Preparation errors that reached the patient (13/81 [16.1%]) occurred significantly less often than administration errors ($P = .002$) and prescribing errors ($P = .021$). When errors that reached the patient were classified by the modified 5 R's scheme, "wrong time" errors (29/81 [35.8%]) and "wrong dose" errors (27/81 [33.3%]) were significantly more common than all other error types, but there was no evidence that they were different from one another ($P = .958$). Medications that were prescribed for the correct frequency but given at the wrong time were the most common specific error subtype that reached the patient (21/81 [26.0%]; Supplementary Table S5).

Errors that reached the patient occurred most frequently on Fridays (20/81 [24.7%]), followed by Mondays, Tuesdays, and Thursdays (12/81 [14.8%]; Table 2). Reported errors that reached the patient occurred less frequently on Saturdays and Sundays than other days of the week (Saturdays, 6/81 [7.4%]; Sundays, 8/81 [9.9%]), though this difference did not reach statistical significance. There was no evidence of a difference between the rates of errors that reached the patient between months when analyzed as month of year. There were too few errors that reached patients in any given month to analyze each of the 25 months as individual time points.

When comparing errors that reached the patient to those that did not by major error type, administration errors comprised a significantly larger proportion of the errors that reached the patient (6/144 [4.2%])

Table 2—Timing of all errors described in Table 1 by day of the week and the month.

	All errors (n = 226)	Errors that reached patient (n = 81)
Day of week error occurred		
Unknown	0 (0%)	0 (0%)
Monday	41 (18.1%)	12 (14.8%)
Tuesday	48 (21.2%)	12 (14.8%)
Wednesday	46 (20.4%)	11 (13.6%)
Thursday	31 (13.7%)	12 (14.8%)
Friday	41 (18.1%)	20 (24.7%)
Saturday	7 (3.1%)	6 (7.4%)
Sunday	12 (5.3%)	8 (9.9%)
Month in which error occurred		
January	9 (4.0%)	3 (3.7%)
February	16 (7.1%)	9 (11.1%)
March	27 (12.0%)	9 (11.1%)
April	22 (9.7%)	10 (12.4%)
May	11 (4.9%)	5 (6.2%)
June	25 (11.1%)	7 (8.6%)
July	29 (12.8%)	9 (11.1%)
August	24 (10.6%)	7 (8.6%)
September	22 (9.7%)	6 (7.4%)
October	16 (7.1%)	5 (6.2%)
November	12 (5.3%)	5 (6.2%)
December	13 (5.8%)	6 (7.4%)

Data are reported as number and percent of total.

than those that did not (38/81 [46.9%]; $P < .001$). Prescription errors occurred significantly less frequently in errors that reached the patient (30/81 [37.0%]) compared to those that did not (102/144 [70.8%]; $P < .001$). There was no evidence of a difference between the proportion of errors due to preparation that reached the patient and those that did not ($P = .355$).

Discussion

Medication errors account for a significant portion of all medical errors in human and veterinary medicine.[1,7,11] Although 74% of veterinarians reported being involved in 1 or more "near misses" over a 12-month period, the field has yet to develop widespread reporting mechanisms that ultimately could reduce the number of errors.[18] The data described here are some of the first to document rates of medication errors by type, drug, and timing in a hospitalized large animal population. We hypothesized that medication error rates in our large animal hospital would be similar to previously published rates and that multiple types of errors would occur. Due to close observation of patient treatment sheets and drug orders by a licensed pharmacist located in the large animal hospital in addition to an effort to encourage error reporting among all hospital staff, a total of 226 medical errors were identified over a 2-year period, 57.5% of which were identified by the pharmacist. In our study, 36.8 errors occurred/1,000 patient visits, which is within the range of error frequencies in human medicine but higher than that previously published in veterinary medicine. Consistent with medication errors in human medicine, errors most frequently occurred in the prescription phase of therapy.[19,20]

Error rates are challenging to compare between studies due to a lack of standardized definitions of error types and methods of reporting. For this study, medication errors were classified in multiple ways to allow for maximum comparison to reports in human and veterinary medicine. The National Coordinating Council for Medication Error Reporting and Prevention classifies medication errors on the basis of the level of patient involvement and harm.[21] These categories range from Category A, in which no actual error occurred but there was a potential for error to occur (an unsafe condition), to Category I, which describes an error that either contributed to or caused a patient's death.[21] Wallis et al[7] used a simplified version of this scale in their study of medical errors in veterinary hospitals that classified each error as an unsafe condition, near miss, harmless hit, or adverse incident.

The errors reported in this study were classified both in this way and by using a system modified from Kron's 5 R's of medication administration, which was also used by Wallis et al[7] and numerous human studies.[15,22] The 5 R's of medication administration (right patient, right drug, right dose, right time, and right route) have long been considered guidelines for nursing professionals and have been modified into the 5 Wrongs in medication error research (wrong patient, wrong drug, wrong dose, wrong time, wrong route).[7,15,20,22] In our study, we also added an additional classification that did not fit into these 5 categories: "dose missed completely." In a human emergency department, incorrect dose errors were the most common type and accounted for 18% of the total errors.[3] In the Wallis et al[7] study, the largest proportion of medication errors overall and specifically in large animal patients were attributed to an error in dosing (overall errors, 199/336 [57.8%]; large animal specific, 13/29 [44.8%]), followed by the wrong drug (overall, 62/336 [18%]; large animal specific, 10/29 [34.5%]). In the same study, incorrect drug errors were significantly more frequently reported in the large animal hospital than in the small animal teaching hospital and small animal private practice.[7] In our study group, "wrong dose" and "wrong time" errors were significantly more likely to occur than all other error types in the overall group and in the subgroup of errors that reached the patient.

Another scheme by which medication errors in human medicine are categorized is by the stage of therapy at which the error occurs: prescription, dispensing, or administration, with some groups also adding monitoring and systems control, which includes improper storage of drugs.[1] Errors in prescribing are the most prevalent type of medication error and make up 29% to 68% of all medication errors in human and veterinary medicine.[1,3,6,7,11,19,20] Our data were consistent with this finding, with errors attributed to prescribing (either by orders on treatment sheets or with pharmacy) accounting for 58.4% (132/226) of total errors. This was also apparent in the modified 5 R's scheme, in which errors caused by either the wrong dose or wrong time made up 65.1% (147/226) of total errors. Though incorrect dosing and timing of therapy can occur during medication preparation, dispensing, or administering, they are initially determined by the prescriber.

To date, no studies have evaluated the timing of medication errors in veterinary medicine and the effect that the presence of veterinary students, interns, and residents have on medication error rates in veterinary teaching hospitals. In human medicine, a phenomenon known as the "July effect" occurs each year when new residents and fellows begin their training programs.[23] When 60 million death certificates were examined over a 28-year period, a 10% increase in fatal medication errors consistently occurred each July with this influx of inexperienced clinicians.[23] Medication orders placed by human surgery residents in July and August were significantly more likely to be associated with medication errors than other months of the year.[24] In veterinary teaching hospitals, veterinary students play a larger role in patient care than in human training programs, which could further influence rates of medication errors. A survey of 70 outgoing and incoming fourth-year veterinary students documented that 85.7% (60/70) of students had been present during a near miss, medical error, or adverse event and 60% (42/70) reported being the individual to cause an event.[25]

In our hospital, fourth-year veterinary students begin their clinical rotations in early May, new interns begin their programs in mid-June, and new residents start in mid-July. Interestingly, May had the second lowest rate of medication errors, which is surprising given that new fourth-year veterinary students became part of the care team at this stage. This low rate may be skewed by the outgoing fourth-year students being present for the first part of the month or by the increased supervision of students by residents, interns, and faculty during this transition period. Similar to human medicine, July had the highest frequency of medication errors, though the differences between July and the other months did not reach statistical significance. It is plausible that with a larger study group, these differences could have been significant. Interestingly, May of 2021 had significantly fewer reported medication errors than the majority of months in the 25-month period. Given that the committee only began regularly documenting medication errors in March 2021 and new fourth-year veterinary students began rotations in May 2021, it is likely that this difference is an effect of underreporting as opposed to a true reduction in errors.

In human medicine, involvement of decentralized pharmacists in hospitals increases medication error identification and allows for intervention before errors reach patients and potentially cause harm.[19,26–28] Decentralized pharmacists are pharmacists located in specific patient care units outside of a centrally located pharmacy within a hospital.[29] In human medicine, pharmacists play a critical role in identifying and reporting medication errors and are more efficient and accurate than nursing staff in this practice.[19,26,28–31] In a human ICU, the involvement of a decentralized pharmacist in patient rounds and their presence in the unit throughout the day reduced adverse medication events by 66%.[28] In a surgical ICU, the presence of a decentralized pharmacist who reviewed patient charts and attended rounds instead of only verifying medication orders led to a significant increase in the number of potential adverse drug events that were identified before they reached the patient, though the effect on errors that reached the patient was not reported.[31] Similarly, the addition of a full-time pharmacist to a pediatric ICU decreased the number of severe medication errors.[32] The pharmacist in our study attended daily rounds and reviewed patient treatment sheets and electronic medical records. A likely explanation for the higher rate of reported medication errors in our study versus that reported by Wallis et al[7] (36.8 vs 6.5 errors/1,000 patient visits) was a result of increased reporting, since only 35.5% of errors in this study reached the patient, as opposed to 56.9%. Moreover, the number of reported errors that occurred on Saturdays and Sundays in our study, when the pharmacist was absent, was significantly lower than the other days of the week, which we suspect was an effect of underreporting. These data suggest that widespread involvement of decentralized pharmacists in veterinary hospitals, like human hospitals, could improve error reporting and reduce medication error rate. Patient drug orders and treatment sheets in our group were evaluated daily, primarily by a decentralized pharmacist located in the large animal hospital, which likely led to a high number of mistakes being caught before they reached the patient. Our data showed that there was a significantly larger proportion of prescription errors that did not reach the patient, suggesting that regular review of patient charts and medication orders prevented errors due to incorrect prescribing.

Due to its retrospective nature, this study had several limitations. All reporting was voluntary; thus, the true incidence of medication errors is unknown and likely higher than what is reported here. A significant portion of errors was identified by the large animal pharmacist and a smaller portion by members of the committee; thus, errors could have been more likely to be missed when those individuals were absent from the hospital. Since errors were recorded by the error, not by the patient, medical record numbers were not always recorded; thus, the exact number of animals affected by the reported errors is unknown. Additionally, the case numbers in a veterinary teaching hospital (especially large animal) are significantly lower than in human medicine and there are fewer technological interventions available for error tracking and automated dispensing and prescribing at this time in veterinary medicine. Finally, because this study was very exploratory in nature and examined many potential factors relating to error, the *P* values in the statistical tests were not adjusted for multiple testing across analyses. All inferential results should be considered preliminary, and follow-up studies should be conducted and all conclusions should continue to be evaluated.

This study highlights the specific types of medication errors that occur in large animal patients in a veterinary teaching hospital and identifies specific steps of drug therapy that are more likely to lead to error and thus can be targeted to improve patient safety. These data provide a framework upon which veterinary medicine can build standardized error reporting strategies to monitor and improve medication errors over time. Lastly, this study is the first to describe involvement of a decentralized pharmacist in a veterinary hospital, which may be of benefit to other institutions. Errors related to prescribing or ordering medications are widely prevalent; thus, veterinarians should be encouraged to implement systemic changes, including error reporting, to reduce medication errors.

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Supplementary Materials

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