Intragastric pH Monitoring

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Buffering of intragastric pH is an accepted treatment modality for prophylaxis against the development of gastric stress ulcers. This method of prophylaxis is commonly based on the pH value acquired by measurement of gastric aspirate. Recent literature suggests pH measurement techniques that involve gastric aspirate specimens have many flaws. The purpose of this study was to compare gastric pH measurements with the use of a nasogastric sensor, meter system, and pH-sensitive test paper. Fifteen hundred paired serial measurements of intragastric pH were obtained on 19 thermally injured patients (16 men and three women, ages 23 to 79 years, total body surface area burn 25% to 80%). A double-lumen tube containing an antimony/graphite pH sensor incorporated into the tip of the tube was inserted with the use of a standard technique. Each tube was in place an average of 5.7 days (range 1 to 15 days). Patients were randomized into two groups. The first group (six patients) received non-acid-buffering prophylaxis therapy. The second group (13 patients) received standard antacid or antacid/H2 histamine-blocking agent combination prophylaxis therapy. Analysis of the 539 paired measurements for the non-acid-buffering revealed a correlation coefficient of $r = 0.532$. The 961 measurements from the group receiving gastric acid buffering revealed a correlation coefficient of $r = 0.569$. Paired t test values for the sample showed a significant difference (18.52, $p < 0.0000$) between measurement techniques. (J BURN CARE REHABIL 1993;14:517-24)

Increasing the intragastric pH of critically injured patients with burns as a prophylactic measure to prevent gastrointestinal hemorrhage is an accepted treatment. Historically it has been reported that gastrointestinal ulcerations will occur in 80% of critically ill patients with thermal injuries if some form of prophylactic therapy is not employed.[1] Stress ulcers, or Curling's ulcers, were first described in 1842, and their incidence has been directly related to burn size. In the thermally injured patient without complications, early mucosal erosions may heal in 1 to 3 weeks without treatment. In those patients with complications a lesion may progress to ulceration with resultant hemorrhage. Ulcer symptoms in the thermally injured population range from none to the development of massive hemorrhage and/or perforation.[2] Because of the potential risk of developing acute stress ulcers, prevention modalities are typically employed for all thermally injured patients with total body surface area involvement of 30% or greater. Most clinical trials recommend buffering or inhibition of acid secretion to maintain the gastric pH between 3.5 and 4.5 as prophylaxis against mucosal disease progression and ulcer formation.[3-15]

The most common method of determining gastric pH is with pH-sensitive test paper, first described by Einhorn in 1910. Several studies have reported that pH-sensitive test paper determines fluid pH accurately. However, this method of intragastric pH monitoring has been recently challenged.[3,12,16-24] In previous validation studies the pH of gastric contents were measured with indwelling glass electrodes, electrodes placed in nasogastric tubes, and gastric aspirate measured with pH-sensitive test paper and/or laboratory pH meters.[12,18-21,26-29] The correlations reported in these studies comparing various measurement techniques range from 0.16 to 1.0.[13,25]

Although buffering of the gastrointestinal tract based on pH measurement has become an integral

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30/1/42204

Table 1. Percent of measurements pH(p) > pH(m), pH(m) > pH(p), and pH(p) = pH(m) by individual patient and group. Group 1 = Non-acid-buffering prophylaxis. Group 2 = Antacid or Antacid/Cimetidine prophylaxis.

Patient	Group	pH(p) > pH(m)	pH(m) > pH(p)	pH(p) = pH(m)
1	1	63.6	31.3	5.0
2	2	43.6	49.0	7.3
3	2	69.6	30.4	0.0
4	1	81.0	17.9	1.1
5	1	46.7	46.7	6.5
6	2	78.8	18.2	3.0
7	2	61.6	36.0	2.3
8	1	0.0	90.0	10.0
9	2	86.2	13.7	0.0
10	2	80.6	15.5	3.9
11	1	48.8	45.2	5.9
12	1	66.1	28.6	5.4
13	2	100.0	0.0	0.0
14	2	78.4	19.6	2.0
15	2	53.0	47.0	0.0
16	2	47.0	50.5	2.6
17	2	100.0	0.0	0.0
18	2	80.0	18.2	1.8
19	2	70.8	26.5	3.2
Sample	Mean	66.8	29.7	3.5

element of stress ulcer prophylaxis, recent literature suggests pH measurement techniques that involve gastric aspirate specimens have many flaws. The employment of a shielded electrode encapsulated in the tip of a nasogastric tube that is attached to a pH meter with digital readout capability offers a unique method of gastric pH monitoring. The purpose of this study was to compare gastric pH measurements using a nasogastric electrode probe and meter system with pH-sensitive test paper. The research hypothesis was that pH-sensitive test paper measurements and indwelling electrode/pH meter readings are equal.

MATERIAL AND METHODS

Nineteen patients (16 men and three women) aged 23 to 79 years who were admitted to the Institute of Surgical Research were studied. The total body surface area of thermal injury ranged from 15% to 81.5% (51.8% ± 20.6%; mean, SD). Informed consent was not required by the institutional review board. All patients required placement of a nasogastric tube for management and were considered to be at risk for gastric ileus or stress ulcer formation. Two groups of patients were included in this study. The first group included six patients who received non-acid-buffering ulcer prophylaxis therapy. This first group was selected to eliminate the potential contamination of samples with antacid. The second group consisted of 13 patients who underwent standard antacid or antacid/H_2 histamine-blocking agent (Cimetidine) combination prophylaxis therapy.

A double-lumen sump tube containing an antimony/graphite pH sensor incorporated into the tip of the tube (GrapHprobe, Zinetic Medical, Salt Lake City, Utah [pH(m)]) was inserted with the use of a standard technique. Placement was confirmed by aspiration of gastric secretions and roentgenogram. The tubes in the study group as a whole were in place an average of 5.7 days (range 1 to 15 days). A standard silver-silver chloride-monitoring skin electrode was placed on unburned tissue to serve as the reference electrode. The precalibrated meter (Graphometer) was connected directly to the nasogastric tube. Digital readings of gastric pH units were recorded at least every 2 hours.

Contents from the gastrointestinal tract were obtained after each meter reading by manual aspiration with a 60 cc syringe. A small aliquot of aspirate was placed on a strip of pH-sensitive test paper (Micro Essential Lab, Brooklyn, N.Y., [pH(p)]) capable of measuring pH 1 through 11. After 5 to 15 seconds the paper changes color from red to blue with increasing alkalinity. The color of the paper was com-

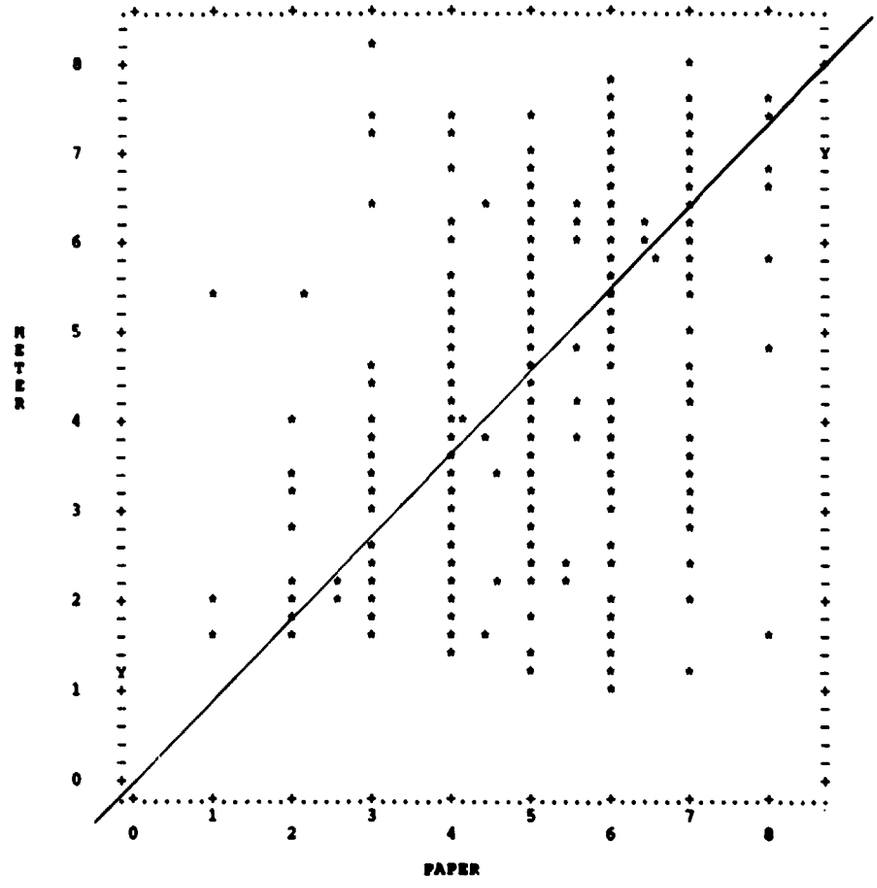

Figure 1. Correlation of pH measurements made with disposable Graphprobe pH sensor and gastric aspirate measured with pH test paper in patients who received non-acid-buffering prophylaxis therapy ($r = 0.532$). Line indicates theoretic complete agreement.

pared with a chart provided by the manufacturer for conversion to pH measurement. The aspirates were analyzed even in the presence of blood, antacid, or bile and were considered representative of the range of samples in clinical practice.

Both the meter and pH test paper were tested in vitro with the use of Fisher Scientific certified buffer solutions. Three buffered solutions with pH of 4, 7, and 10 were used. Three meters and three tubes were evaluated in vitro. A standard silver-silver chloride skin electrode was placed on one of the investigators and was connected to the GrapHprobe tube. The electrical bridge was established during validation trials by the investigator placing a finger and the tip of each GrapHprobe in the buffer solution concurrently. The reproduction of measurement between tubes was within the manufacturer's standards of ± 0.2 for all three GrapHprobe tubes and meters. The investigator determined the pH of the three clear buffer solutions correctly using five different rolls of pH-sensitive test paper from the bedside. The order of the buffer solutions was altered by an impartial observer, and the values were known only by that observer.

STATISTICS

Regression analysis was conducted to determine the correlation of pH(m) to pH(p). Statistical differences between pH(m) and pH(p) were determined by *t* test with a 0.01 level of significance. Statistical analysis was conducted with the BMDP statistical package (BMDP, Los Angeles, Calif.).

RESULTS

Nineteen patients were studied for an average of 5.78 days with a range of 1 to 15 days. One thousand five hundred paired measurements of gastric pH were recorded for analysis. For the total sample the pH(m)

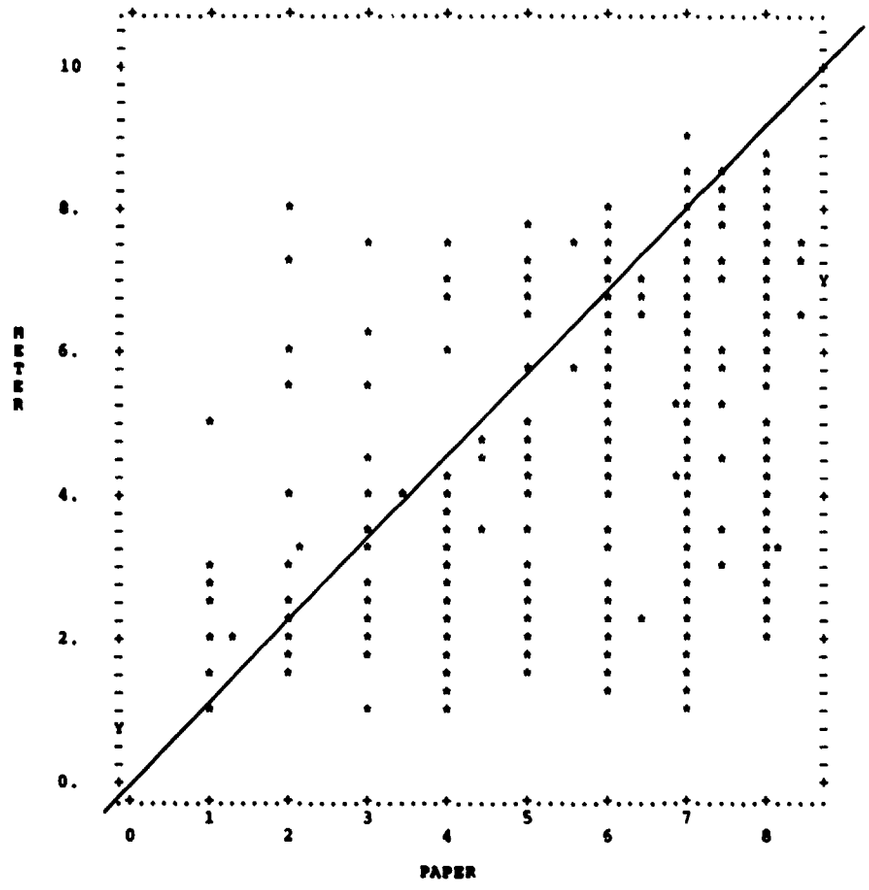

Figure 2. Correlation of pH measurement made with disposable Graphprobe pH sensor and gastric aspirate measured with pH test paper in patients who received gastric buffering ($r = 0.569$). Line indicates theoretic complete agreement.

Table 2. Difference between pH measurement technique

	pH-Sensitive paper	pH Sensor/meter	Sample size	r	p
Non-acid-buffered	5.29 ± 0.06	4.82 ± 0.08	539	0.532	<0.001
Standard buffered	6.44 ± 0.05	5.47 ± 0.06	961	0.569	<0.001
Total	6.03 ± 0.04	5.24 ± 0.05	1500	0.572	<0.001

Mean ± SEM Value.

varied from 1.0 to 8.9, whereas the pH(p) varied from 1.0 to 8.5. In the non-acid-buffering group the pH(m) varied from 1.0 to 8.1, whereas the pH(p) ranged from 1.0 to 8.0. In the second group who received gastric buffering, pH(m) readings ranged from 1.0 to 8.9, and the pH(p) ranged from 1.0 to 8.5. Only 3.5% of the total pH measurements were equal (Table 1).

Analysis of the 539 paired measurements for the non-acid-buffered group revealed a correlation coefficient of $r = 0.532$ (Figure 1). The 961 measurements from the group receiving gastric buffering revealed a correlation coefficient of $r = 0.569$ (Figure 2). Although the data show a correlation between the two methods of measurement, this correlation is not strong enough to support equality. A value of less than 1.0 validates the acceptance of the null hypothesis, which states that pH(m) and pH(p) measurements are not equal. The paired t test values for the sample showed a significant difference (18.52, $p < 0.0000$, DF 1499) between the measurement techniques (Table 2).

Because of the weak correlation between the two methods, it was decided to evaluate the potential effect each technique might have on the clinical decision to initiate or adjust gastric-buffering therapy.

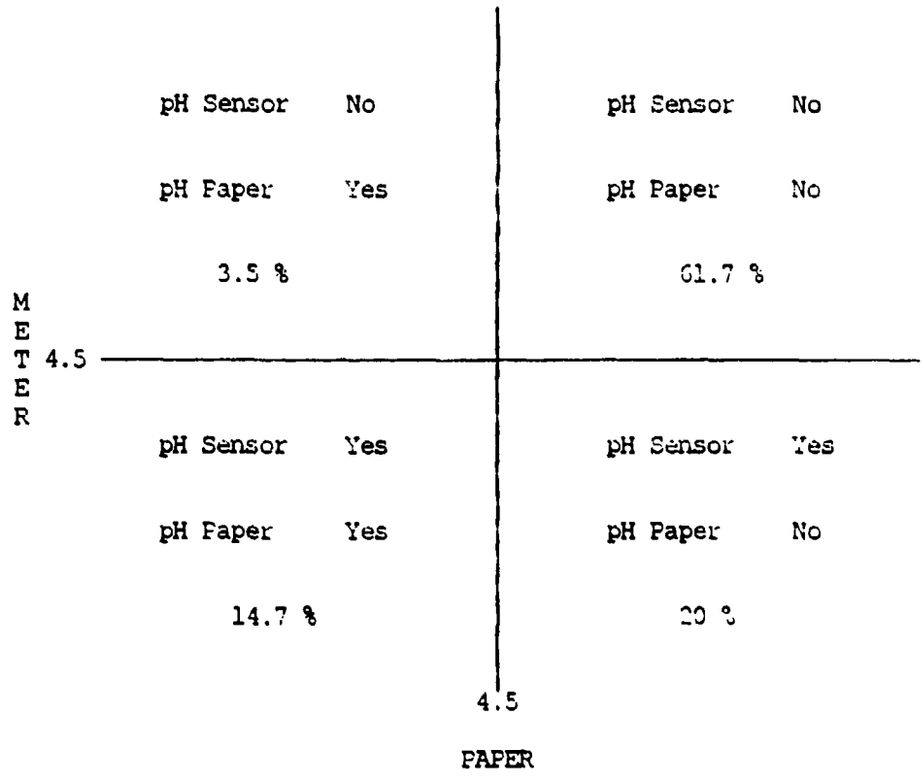

Figure 3. Potential decision matrix for initiation or adjustment of gastric buffer therapy at pH 4.5 for gastric ulceration prophylaxis.

The pH(m) and pH(p) data were divided into quadrants at the pH reading of 4.5. If the determination for therapy is based on a pH value greater than or less than 4.5, then the data supports/rejects therapy as follows: left upper quadrant: pH(m) rejects and pH(p) supports therapy; right upper quadrant: pH(m) and pH(p) reject therapy; left lower quadrant: pH(m) and pH(p) support therapy; and right lower quadrant: pH(m) supports and pH(p) rejects therapy.

Review of the data for the entire sample indicates that when pH(p) was used, 20% of the time patients would not receive buffering therapy when the pH(m) indicated that treatment was necessary. Conversely, if the decision to treat was based upon pH(m) and not pH(p), then patients would not receive buffering therapy only 3.5% of the time when the pH(p) suggested that therapy was indicated (Figure 3).

DISCUSSION

The suspicion that pH-sensitive test paper may give inaccurate measurements has resulted in the development of several methods to measure intragastric pH. The main focus of this study was to compare the data obtained using a commercially prepared nasogastric tube with a sensor probe placed in the distal tip of the tube (probe/meter system) with that obtained by use of pH-sensitive test paper.

In this study the pH(m) values were greater than pH(p) values 29.7% of the time and were less than pH(p) values 66.8% of the time. The two measurements were equal just 3.5% of the time. The differences in the two methods may be due to variation in pH measured at the GrapHprobe and pH measured in an aspirate consisting of pooled secretions. In making the decision of which technique to use, consideration must be given to the disadvantages of the two techniques (Table 3).

A potential disadvantage of the probe/meter system in the thermally injured patient population is the limited availability of unburned tissue for placement of the reference electrode. Without good skin contact with the electrode, the data may be flawed. When pH-sensitive test paper is used, consideration must be given to the measurement process. The use of the paper requires interpretation of gradual color change and measurement in whole numbers, which is subject to error. Color blindness of the individual making the measurement could also be a factor. When using the pH paper one may obtain an aspirate sample that is contaminated with antacids, bile, blood, or med-

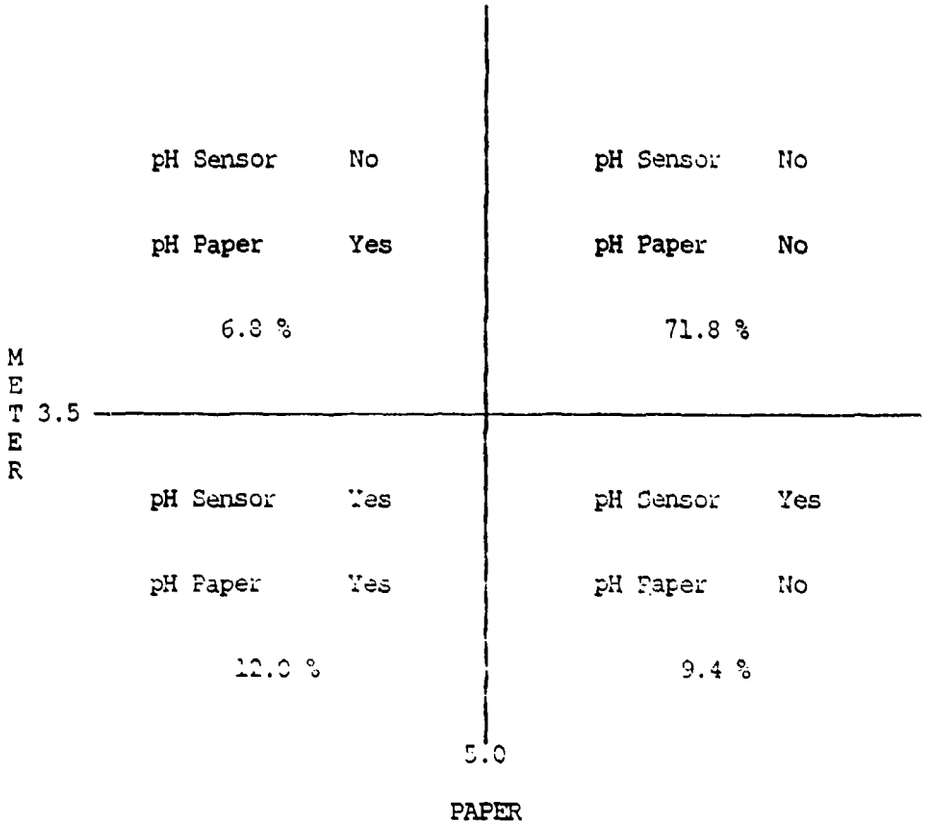

Figure 4. Decision matrix for initiation or adjustment of prophylactic therapy based on pH-sensitive paper reading of 5.0 and pH probe/meter system reading of 3.5.

Table 3. Advantages and disadvantages of each measurement technique

pH-Sensitive test paper		pH Sensor/meter system	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Required equipment readily available in critical care units	Consumable supplies costs escalate with prolonged monitoring	Limited consumable supply costs	Initial cost of the sensor and meter
Cost to initiate monitoring is low	Staff is placed at risk of exposure to gastric secretions	Limited exposure of staff to gastric secretions	Meter reading is frequently lower, which may increase pharmaceutical usage to increase pH
	Labor costs escalate with extended monitoring	Decreased labor costs	
	Requires approximately 5 minutes of direct nursing time per reading	Requires approximately 1 minute of direct nursing time per reading	

ications that can affect the pH measurement. Moreover, obtaining an adequate aspirate sample is often difficult when there are limited secretions.

This study does not resolve the question of which technique produces correct data. The poor correlation between the probe/meter measurements and the paper measurements may support the hypothesis that it is difficult to obtain a "pure" gastric pH measurement. Evaluating the data relative to a "decision matrix" for treatment indicates advantages of using the probe/meter system over the pH-sensitive test paper technique.

If pH(p) is thought to be the standard, the data indicate that the paper technique would not have

Table 4. Cost analysis for probe/meter system versus aspiration/pH-sensitive test paper technique

Material required	Quantity per 24 hrs	Unit cost	Day 1	Day 2	Day 3	Day 4	Day 5
			pH-Sensitive test paper technique				
NG Tube	1	6.88	6.88	0.00	0.00	0.00	0.00
60 ml Syringe	1	0.46	0.46	0.46	0.46	0.46	0.46
30 ml Med cup	12	0.04	0.48	0.48	0.48	0.48	0.48
pH Test paper	12	0.12	1.44	1.44	1.44	1.44	1.44
Gloves	12	0.82	9.84	9.84	9.84	9.84	9.84
Paper towel	12	0.05	0.60	0.60	0.60	0.60	0.60
RN labor	12		19.00	19.00	19.00	19.00	19.00
Daily costs			38.70	31.82	31.82	31.82	31.82
Cumulative costs			38.70	70.52	102.34	134.16	165.98
			pH Sensor/meter system				
pH sensor tube	1	30.00	30.00	0.00	0.00	0.00	0.00
Meter	1	0.55	0.55	0.55	0.55	0.55	0.55
RN Labor	12		3.80	3.80	3.80	3.80	3.80
Daily costs			34.35	4.35	4.35	4.35	4.35
Cumulative costs			34.35	38.70	43.05	47.40	51.75

RN labor costs are based on $19.00 per hour. Estimated meter costs are based on $200 with replacement on an annual basis.

recommended treatment 20% of the time compared with probe/meter measurements. Conversely, if pH(m) is considered the standard, then therapy would not have been administered only 3.5% of the time.

Similar results were obtained in a study by Eisenberg, Cort, and Zuckerman.[30] They found that in patients receiving antacids a poor correlation coefficient existed between the pH paper and pH probe method ($r = 0.56$; $n = 22$). The mean pH value for 16 of 22 patients was higher when obtained by paper versus the GrapHprobe/meter system.

Many of the advantages and disadvantages are based on resource use, which leads to a cost analysis of the techniques. The cost of the probe/meter system is recovered through decreased requirements for syringes, pH test paper, and gloves, as well as through personnel time savings (Table 4). When the probe/meter system is used in our unit, the projected annual savings is $32,000.

In our study sample no upper gastrointestinal hemorrhages that required surgical intervention occurred. In fact, since 1975 no patient at our institute whose gastric pH has been maintained at 5 or greater with the use of pH-sensitive paper has required surgery for upper-gastrointestinal hemorrhage.

Because the pH(m) measurements were one to two units less than the pH(p) and pH(p) reading of 5 appears to have been associated with protection, a new decision was constructed. In the new matrix the divider for pH(m) readings is lowered to 3.5 and is raised to 5.0 for pH(p). These changes lower the potential threat of overtreatment from 20% to 9.4% and decrease the potential for increased pharmaceutical usage (Figure 4).

CONCLUSION

This study established a weak correlation between the probe/meter and pH-sensitive paper techniques for obtaining gastric pH measurements. The null hypotheses that the two techniques produce measurements that are not equal was validated. Although the question of which technique provides more accurate pH measurement data was not resolved, data indicate that the probe/meter system has greater advantages than does the test paper technique in reducing potential errors in prophylactic treatment decisions, reducing material and personnel costs, and in increasing staff safety through decreased exposure to gastric aspirate.

We thank the nurses at US Army Institute of Surgical Research, Fort Sam Houston, Texas, for collecting and recording the pH measurements.

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