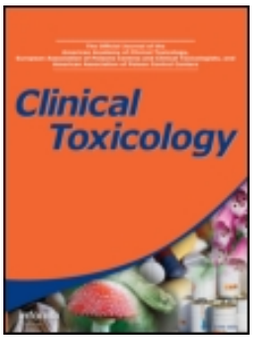

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Gaseous emissions at the site of the Delphic Oracle: Assessing the ancient evidence

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LETTERS TO THE EDITOR

Caustics and steroids: A case of Simpson's Paradox

To the Editor:

The recent article by Fulton and Hoffman provides an excellent example of Simpson's Paradox (1,2). Simpson's Paradox states that "It is not necessarily true that averaging the averages of different populations gives the average of the combined population" (3). In fact, comparing the average of the combined populations and the average of the averages of the individual populations can lead to conclusions which are quite the opposite.

For example, a comparison of Derek Jeter's batting average and David Justice's batting average during 1995 and 1996 seasons reveals that David Justice had a better batting average each year (see Table 1). However, if all the at-bats in both years were pooled for the two years, then Derek Jeter would have the better batting average. Conversely, if the mean batting average for the two seasons is compared, then David Justice has the better average (4).

To demonstrate this paradox in the case of steroids and second degree caustic esophageal injuries, we can use the author's data to create an analysis that compares the average of the combined population (the rate of stricture formation from the pooled data) to the average of the averages of the different populations (the mean of the rate of stricture formation from each of the studies) (see Table 2).

If the two populations are compared as the author have, that is by pooling the data without a weighting variable or statistical treatment, then the rate of stricture formation without steroids (19%) is greater than the rate of stricture formation with steroids (12%). This would appear to support the use of steroids. Paradoxically, if we compare the arithmetic means of the rates of stricture formation from each of the individual studies, the mean rate of stricture formation without steroids is 15% and the mean rate of stricture formation with steroids is 20% - leading to quite the opposite conclusion. Neither of these approaches is statistically valid because studies cannot be combined without a weighting process such as meta-analysis. Furthermore, because only three of the studies have a control group, a strict meta-analysis can only include those three studies. One prior meta-analysis of those three studies found when steroids were used to prevent stricture formation, despite the pooled analysis suggesting a possibly protective effect. (5) also found steroids offered no protection. Another study that attempted to pool data (6).

Since prior meta-analysis of the three investigations with both a control and a treatment group failed to support the use of steroids in second degree esophageal burns, the authors conclusions that the existing data fail to support the use of steroids is reasonable. However, the pooled data appear to demonstrate a benefit to steroids where the mean data appear to demonstrate harm from steroids and this is an example of Simpson's Paradox.

Table 1. A comparison of Derek Jeter's batting average and David Justice's batting average during the 1995 and 1996 seasons illustrating Simpson's paradox prepared from reference (4)

		Derek Jeter		David Justice	
		hits/at bats	batting average	hits/at bats	batting average
By Season	1995	12/48	.250	104/411	.253
	1996	183/582	.314	45/140	.321
Pooled		195/630	.310	149/551	.270
Mean			.282		.287

Table 2. Comparison of stricture formation rates using pooled data and mean data extracted from Table 1 of ref. (1)

	Steroid-treated	not steroid-treated
Study no.	# strictures/ total # patients (%)	# strictures/ total # patients (%)
1	1/15 (7)	0/5 (0)
2	4/18 (22)	No control group
3	7/19 (37)	No control group
4	1/6 (17)	No control group
5	1/25 (4)	No control group
6	0/91 (0)	No control group
7	No control group	2/32 (6)
8	5/9 (56)	No control group
9	2/9 (22)	4/11 (3)
10	1/6 (17)	No control group
11	3/28 (11)	No control group
12	5/18 (28)	0/3 (0)
13	No control group	10/33 (30)
Stricture formation rates		
Pooled rate	30/244 (12)	16/84 (19)
Mean rate	(20)	(15)

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References

1. Fulton JA, Hoffman RS. Steroids in second degree caustic burns of the esophagus: A systematic pooled analysis of fifty years of human data: 1956–2006. Clinical Toxicology 2007; 45:402–408.
2. Simpson EH. The interpretation of interaction in contingency tables. Journal of the Royal Statistical Society 1951; 13:238–241.
3. Weisstein, Eric W. "Simpson's Paradox." From *MathWorld*—A Wolfram Web Resource. Accessed July 31, 2007, at http://mathworld. wolfram.com/SimpsonsParadox.html>
4. Ross K. A Mathematician at the Ballpark: Odds and Probabilities for Baseball Fans. Pi Press, 2004:12–13.
5. LoVecchio F, Hamilton R, Sturman K, Hoffman RS. A meta-analysis of the use of steroids in the prevention of stricture formation from second degree caustic burns of the esophagus (abstract). J Toxicol-Clin Toxicol 1996; 34:579–580.
6. Pelclova´ D, Navra´til T. Corrosive Ingestion: The Evidence Base. Are Steroids Still Indicated in Second and Third-Degree Corrosive Burns of the Oesophagus? J Tox Clin Tox 2004; 42: 395–564.

Gaseous emissions at the site of the Delphic Oracle: Assessing the ancient evidence

To the Editor:

In a recent paper by Foster and Lehoux (1), the two authors comment on the results of our team's study of evidence for gaseous emissions at the site of the ancient Delphic Oracle in central Greece. Judging from their comments, Foster and Lehoux appear to be insufficiently familiar with the ancient sources, with scientific method, and with the site of Delphi itself. Their paper attempts to reassert the orthodox position of 20th century classical scholars, who have routinely maintained that there is no truth to the ancient tradition of unusual geological phenomena and activity at the oracle site.

With regard to the ancient sources, it is misleading for them to state that "almost no ancient sources" mention the fissure and the intoxicating *pneuma* (a Greek term that can mean gas, wind, breath, or vapor, depending upon its context) in the oracular temple. Only a small fraction of ancient literature survives: there is, for example, only one reference to the Parthenon at Athens in the entire literature of the 5th century BC, when the temple was constructed. What counts is not quantity but quality, and in the case of the Delphic Oracle we are fortunate to have three essays by the Greek writer Plutarch, who served as priest at Delphi for many years and was an eye-witness to the oracular sessions. Plutarch makes it clear that from time to time, there was a sweet-smelling emission from the *adyton* or oracular chamber. He attributes the weakness of the emission in his own time to such geological activity as earthquakes that sealed up the vents in the rock, or limited amounts of the "vital essence" in the rock itself. Plutarch records routine oracular trances, after which the woman who spoke the oracles appeared like a runner after a race or a dancer after an ecstatic dance. And he contrasts these with extraordinary cases in which the woman raved and flung herself about in a delirium. Throughout his writings, Plutarch makes it clear that the oracle's power was believed to derive from a physical, geological source.

Foster and Lehoux also misunderstand the process of standard scientific method, which starts with a hypothesis and then tests the hypothesis against data. This may appear "circular", but it is the opposite of circular reasoning, since the hypothesis is not accepted unless it is confirmed by the evidence. In the case of our research, we tested the hypothesis that ancient reports about the oracle were accurate by conducting geological and archaeological surveys at Delphi and analyzing gases in ground water from modern springs at and in travertine rock laid down by the springs at the time the oracle was active. The data confirmed that the rock beneath the temple was fractured by geological faults, and that the spring water, ancient and modern, contained intoxicating light hydrocarbon gases in higher than atmospheric concentrations. These findings confirmed the accuracy of the ancient tradition, which Foster and Lehoux wish to deny.

A serious error occurs in Foster and Lehoux's statements about ethylene. They use a figure of 2.2 for the atmospheric destruction of ethylene, the sweet-smelling hydrocarbon which we identify with Plutarch's sweet-smelling emission. This short time, according to them, would not allow sufficient concentrations of ethylene to develop in the temple crypt. However, if they had read their own source with attention, they would have discovered that the process is photochemically driven and depends on sunlight (2). There was no sunlight in the depths of the temple where the *adyton* was located, and therefore ethylene could have lasted considerably longer as a free gas.

It is not surprising that ethylene was not detected in the travertine rock around the temple. Ethylene is highly reactive. Rather than surviving through the centuries, the original ethylene would be chemically altered to form ethane and/or methane, also intoxicating hydrocarbons, which were found in the travertine.

A second geological study of the Delphic Oracle site was published by Etiope et al. in *Geology* 2006 (3). A team of five Italian and Greek geologists confirmed the presence of active faults and gaseous emissions at Delphi. They suggest that benzene was the sweet smelling gas that triggered the oracular trance. Whatever the exact identification of the gas

may be, their research supported the conclusion that intoxicating hydrocarbons formed the "active ingredient" in the *pneuma* described by the ancient writers. Additionally, within the last year a study by a team of archaeologists and geologists has documented a second oracular shrine at a Temple of Apollo in Hierapolis, Turkey constructed by the Greeks directly over an active geological fault with a gaseous vent from a cavern (the *Plutonion*) (4). Again ancient writers linked these toxic emissions to the religious cult. Ground penetrating radar has identified a previously unknown man-made subterranean chamber under the temple on the fault line, interpreted to be an entrance to the cavern. While in the case of Hierapolis the gaseous vent emits carbon dioxide, it again demonstrates the ancient tradition of locating oracular buildings and temples of Apollo on specific geological phenomenon. Foster and Lehoux are also unfamiliar with basic geology and plate tectonics. Plutarch claimed that the emission had weakened through time. Natural changes in the flow rate of springs and associated gases are a common phenomenon, especially in highly seismic areas. Emission rates following earthquakes remain high for years and slowly decrease over time. In any case, the permeability and porosity of fault zones in limestone complexes are reduced by the formation of calcite and travertine crusts laid down by springs. Spaces are then frequently opened up again as a result of vibrations caused by strong earthquakes elsewhere in the tectonic zone. The recurrence rate for quakes with magnitude around 6 in the Corinth rift zone has been estimated at between 100 and 150 years. Therefore, Delphi has been shaken repeatedly through the centuries with related consequences for gas emissions.

For a full understanding of ancient writers, it is important to visit and study the sites that they described. For example, Foster and Lehoux make much of the small amount of water currently flowing from the Kerna spring above the temple. If they were familiar with Delphi, they would see that while the water presently seeps from a minor crack and collects in a small reservoir, its flow has been significantly reduced due to a major diversion that has affected all springs along the Kerna fault. In recent years, local engineers have drilled several holes and constructed reservoirs in the Kerna fault zone above the oracular site. From there, the water that used to flow through the sanctuary is now piped to modern Delphi. Additionally, the flow in the past was clearly greater than today as evidenced by the existence of thick travertine curtains that cover the retaining wall beside the temple. These deposits indicate clearly that the volume of groundwater and associated gases was significantly larger in the past.

The archaeological evidence of the temple itself shows that the design and layout was adapted to accommodate certain geological features. The asymmetrical inner space of the temple provided for an alcove on the southern side where a spring must have emerged, since a series of tunnels and conduits was constructed through the massive stone foundations to drain the spring water out of the *adyton*. The ancient architects would not have constructed such a feature if it had not been necessary.

In conclusion, ancient authors referred to geological phenomena at the site of the Delphic Oracle – a fissure, a spring, and a gaseous emission – and two recent scientific surveys including our own have demonstrated that these features exist. In our view, the burden of proof now rests with the detractors of Plutarch and the other sources, rather than with those who take their testimony seriously.

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References

1. Foster J, Lehoux D. The Delphic Oracle and the ethylene-intoxication hypothesis. Clin Toxicol 2007; 45:85–89.
2. Assessment report on ethylene for developing ambient air quality objectives, 2002. (accessed April 9, 2007 at http://www3.gov.ab.ca/protenf/publications/assessRep-ethylene.pdf).
3. Etiope G, Papatheodorou G, Christodoulou D, Geraga M, Favali P. The geological links of the ancient Delphic Oracle (Greece): a reappraisal of natural gas occurrence and origin. Geology 2006; 34: 821–824.
4. Negri S, Leucci G. Geophysical investigation of the Temple of Apollo (Hierapolis, Turkey). J Archeol Sci 2006; 33:1505–1513.

Hypertonic saline: An alternative therapy in TCA overdoses failed to respond sodium bicarbonate

To the Editor:

I would like to thank Dr. Bebarta et al. for their interesting case report of a tricyclic antidepressant (TCA) overdose presenting with a Brugada pattern that failed to respond sodium bicarbonate and discuss the use of hypertonic saline (7.5%) as an alternative therapy in TCA overdoses that fail to respond the classical therapy.

The evidence supporting the usage of hypertonic saline is limited and contradictory. One study showed no improvement when hypertonic saline was added to sodium bicarbonate therapy (3). In two recent studies (4,5) hypertonic saline corrected hypotension and QRS prolongation in experimental swine models. In the first study, 7.5% saline and 6% dextran were found to be effective in TCA overdose while normal saline was not (4). In the second study, 7.5% saline was found to be superior to both sodium bicarbonate and hyperventilation in reversing QRS prolongation and hypotension (5). However, hypertonic saline failed to establish an alkaline pH, which was shown to prevent cardiac arrhythmias (3). A more recent publication reported a 29-year-old 78 kg woman who presented to the emergency department after ingesting approximately 8 g of nortriptyline. The patient was hypotensive and had a QRS duration of 124 msec. She transiently improved following a bolus 3 L normal saline and 200 mL (4 ampoules, 8.4% $NaHCO_3$) of sodium bicarbonate. However, in the intensive care unit she had recurrent hypotension resistant to an additional 5 L normal saline and to vasopressor therapy (dopamine 20 mcg/kg per minute and norepinephrine at 22 mcg/minute). Hypertonic saline (200 mL, 7.5% NaCl) was administered and the QRS prolongation and hypotension improved within three minutes. In another study, $NaHCO_3$ was found to be more effective in reversing the cardiac effects of TCA than alkalinazation and sodium chloride alone (8).

The patient reported by McKinney (6) improved after the administration of 200 ml of 7.5% NaCl (approximately 175 mEq of sodium) despite the lack of response to 200 ml NaHCO3 (approximately 200 mEql of sodium). Dr. Bebarta et al. administered a total of 300 mEq sodium by giving NaHCO3, with no response in the Brugada pattern. It would be interesting to know if the Brugada pattern would have responded to the administration of hypertonic saline.

The side effects of hypertonic saline (hypernatremia and hyperchloremic acidosis) should be considered. Hypernatremia developed in the swine group treated with hypertonic saline (pre-treatment sodium levels of 138 ± 5 mEql/L vs post-treatment levels of 157 ± 4 mEql/L) whereas there was no hypernatremia in the other groups (5).

In conclusion, recent experimental studies support the effectiveness of hypertonic saline, but the data proving the best therapy in TCA overdoses are conflicting. Further studies are needed to identify the clear effects of hypertonic saline, alkalinization, and $NaHCO_3$.

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References

1. Bebarta VS, Waksman JC. Amitriptyline-induced Brugada pattern fails to respond to sodium bicarbonate. Clinical Toxicology. 2007; 45:186–188.
2. Wrenn K, Smith BA, Slovis CM. Profound alkelemia during treatment of tricyclic antidepressant overdose: a potential hazard of combined hyperventilation and intravenous bicarbonate. Am J Emerg Med. 1992; 10:553–555.
3. Nattel S, Mittleman M. Treatment of ventricular tachyarrhythmias resulting from amitriptyline toxicity in dogs. J Pharmacol Exp Ther. 1984; 231:430–5.
4. McCabe JL, Menegazzi JJ, Cobaugh DJ, Auble TE. Recovery from severe cyclic antidepressant overdose with hypertonic saline/dextran in a swine model. Acad Emerg Med. 1994;1(2):111–5.
5. McCabe JL, Cobaugh DJ, Menegazzi JJ, Fata J. Experimental Tricyclic Antidepressant Toxicity: A Randomized, Controlled Comparison of Hypertonic Saline Solution, Sodium Bicarbonate, and Hyperventilation. Ann Emerg Med 1998; 32:329–333.
6. McKinney PE, Rasmussen R. Reversal of Severe Tricyclic Antidepressant-Induced Cardiotoxicity with intravenous hypertonic saline solution. Ann Emerg Med. 2003; 42:20–34.
7. Nattel S, Keable H, Sasyniuk BI. Experimental amitriptyline intoxication: electrophysiologic manifestations and management. J Cardiovasc Pharmacol. 1984; 6:83–9.
8. Sasyniuk BI, Jhamandas V. Mechanisms of reversal of toxic effects of amitriptyline on cardiac Purkinje fibers by sodium bicarbonate. J Pharmacol Exp Ther 1984; 231(2):387–94.