Adverse Renal and Metabolic Effects Associated with Oral Sodium Phosphate Bowel Preparation

Eliot C. Heher,* Samuel O. Thier,†‡ Helmut Rennke,† and Benjamin D. Humphreys§
*Department of Medicine, Division of Nephrology, Massachusetts General Hospital, Boston, Massachusetts; †Department of Medicine and Healthcare Policy, Harvard Medical School, Boston, Massachusetts; ‡Renal Pathology and §Renal Division, Brigham and Women’s Hospital, Boston, Massachusetts

Colorectal cancer can be prevented by the removal of adenomatous polyps during screening colonoscopy, but adequate bowel preparation is required. Oral sodium phosphate (OSP), an effective bowel purgative, is available over the counter and requires a substantially lower volume than polyethylene glycol-based preparative agents. Accumulating reports implicate OSP in electrolyte disturbances as well as acute kidney injury (AKI) in a syndrome termed phosphate nephropathy (a form of nephrocalcinosis). Despite published case reports and case series, the actual incidence, risk factors, and natural history of phosphate nephropathy remain largely undefined. Several recent observational studies have provided new information on these important issues while supporting a link between OSP and acute phosphate nephropathy as well as the development of chronic kidney disease in elderly patients, many of whom had a normal serum creatinine at the time of OSP ingestion. This review summarizes current knowledge about the renal complications of OSP, risk factors for its development, and the pathophysiology of acute and chronic kidney damage in nephrocalcinosis.

Approximately 14 million colonoscopies are performed in the United States yearly for colon cancer screening, and efforts to increase screening rates have included endorsements by celebrities (1,2). The diagnostic accuracy and cost-effectiveness of colonoscopy are closely related to the quality of the colon preparation, and yet methods to safely, effectively, quickly, comfortably, and affordably prepare the colon remain elusive (3). In clinical trials, nearly 75% of subjects undergoing bowel preparation report adverse events, most commonly abdominal distention, nausea, vomiting, abdominal pain, and dizziness (4).

Methods of bowel preparation have evolved from the traditional approach of dietary restriction and enemas, which although effective, are time-consuming and uncomfortable (5). An early preparative agent was mannitol, but it results in the production of methane, hydrogen, and other flammable gases and has been associated with fatal colonic explosions during polypectomy and electrocautery (6,7). Large volumes of saline or balanced electrolyte lavage solutions are also effective, but their use results in significant net fluid and electrolyte absorption. A significant advance occurred when Davis et al. at Baylor University substituted nonabsorbable sodium sulfate in place of sodium chloride and added polyethylene glycol for osmotic effect (8). They called this iso-osmolar, nonabsorbable solution “GoLytely,” although it is more generally known as polyethylene-glycol electrolyte lavage solution (PEG-ELS) (8). A version known as Nu-Lytely, formulated without the unpalatable ingredient sodium sulfate, became available in 1990 (9). Recent formulations have combined half-dose Nu-Lytely (2 L rather than 4 L) with Bisacodyl tablets (called Half-Lytely).

Despite the effectiveness and relative safety of PEG-ELS, many patients complain about the taste and the large volume they must drink. The search for alternatives to standard PEG-ELS preps led back to oral sodium phosphate (OSP) preparations, which have existed for many years. In early studies comparing the two approaches, patients and colonoscopists preferred OSP (10–12). A recent meta-analysis concluded that OSP preps result in better bowel cleansing, perhaps because patients are more likely to complete them (13). An industry-sponsored study that compared OSP tablets with PEG-ELS + bisacodyl concluded that OSP is more efficacious and better tolerated (4).

Like lactulose and milk of magnesia (magnesium hydroxide), OSP preparations are osmotic purgatives that obligate water excretion into the intestinal lumen to maintain its isotonicity with plasma (in contrast to the kidney, the proximal small intestine does not create or maintain an osmotic gradient between the luminal and blood side) (14). The retention of water in the bowel lumen results in peristalsis and colonic evacuation (15). It is the high sodium and phosphate content of OSP preps, which render them hyperosmolar. Each 45-ml dose of Fleet’s Phospho-soda contains 5 g of sodium and 17.8 g of phosphate, yielding a solution with an osmolarity of 16,622 mOsm/L (748 mOsm/45 ml) (14). The amount of elemental phosphorus in two 45-ml doses is approximately 11.5 g, a substantial load compared with the typical daily dietary intake of 1 to 1.5 g (16). Two OSP tablet preparations are also approved for use: Visicol, which is similar in content to Fleet’s Phospho-soda, and Osmo-
Metabolic Disturbances Associated with Bowel Preparation: a “Forgotten Menace?”

Metabolic disturbances, including hyperphosphatemia, hypocalcemia, hypernatremia, hyponatremia, hypokalemia, and anion-gap metabolic acidosis, have been reported in association with OSP preps, sometimes accompanied by volume depletion and AKI typically attributed to tubular injury (16,18–20). Because 1 to 1.8 L of hypotonic fluid is lost after the use of a 45-ml dose of OSP solution, dehydration, volume depletion, and hypernatremia are not uncommon (17,21,22). Osmotic diuresis resulting from the high concentration of intratubular phosphate may contribute to the volume depletion (23). Central pontine myelinolysis has been reported in a patient whose sodium rose to 180 mMol/L after an OSP prep (24).

In contrast, when excess water is retained during bowel preparation, severe hypernatremia and its associated complications can occur (25,26). Two deaths from hypernatremia have been reported in patients with end-stage renal disease who received PEG-ELS, which has also resulted in hypernephric seizures in patients with normal renal function (26,27). In these cases, the affected patients consumed significant quantities of hypotonic fluids in addition to the PEG-ELS prep. The nonosmotic release of antidiuretic hormone, possibly as a result of nausea and stress, appears common during colonoscopy and likely impairs the ability to excrete free water (28). Patients with significant chronic kidney disease (CKD) may on rare occasion experience a significant increase in plasma volume after PEG-ELS and decompensated heart failure may result (29,30).

Hyperphosphatemia after OSP ingestion routinely occurs even in individuals with normal renal function, with one study reporting a rise in the mean serum phosphate from 3.7 to 7.3 mg/dl (10,31,32). In another study, calcium-phosphate products exceeding 65 were observed in more than one third of normal volunteers (21). Severe hyperphosphatemia complicated by hypocalcemia and tetany have been reported in those with normal renal function (Figure 1) (33–37). Older patients, those with abnormal gut motility (which enhances phosphate absorption) and those who have received repeated doses of OSP, have experienced particularly severe electrolyte disturbances and deaths (38–41). Enemas that contain phosphate can also result in severe hyperphosphatemia and AKI as well as other complications (42,43).

Some authorities recognized the risk of electrolyte disturbances from OSP early on and counseled against their use, particularly in patients with comorbid conditions such as kidney, liver, or heart disease (44,45). The first FDA review of the safety of OSP occurred in 2001 and resulted in a report urging physician awareness and recommending monitoring of electrolytes in high-risk patients (46). In the face of ongoing reports of metabolic complications, one group termed OSP “a forgotten menace” (36).

Kidney Injury after OSP Bowel Preps: Biopsy Studies

More recent attention has been directed to the possibility that in some patients the deposition of calcium-phosphate crystals after OSP administration may result in AKI. In a 2003 letter to the New England Journal of Medicine, Desmeules et al. reported a 71-yr-old whose creatinine rose from 1.0 to 4.5 mg/dl in a 10-wk period after the use of a OSP solution administered before colonoscopy (47). Analysis of the kidney biopsy specimen by light microscopy, scanning electron microscopy, and x-ray microanalysis confirmed the presence of intratubular calcium-phosphate deposits in the form of hydroxapatite. Kidney function remained abnormal one year later. The authors called the patient’s condition “phosphate nephropathy.”

In 2004, Markowitz et al. at Columbia University extended this report by describing 5 patients who developed AKI after OSP preps, all of whom had distal tubular injury and calcium-phosphate deposits demonstrated on kidney biopsy (48). Subsequently, the same group reviewed 7349 kidney biopsies and identified an additional 16 patients who appeared to have phosphate nephropathy associated with OSP (49). The mean age of the 21 total patients identified by Markowitz et al. was 64, and at baseline 17 of them had good renal function (mean creatinine <1.2 mg/dl). Two thirds (14 of 21) were receiving angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) at the time of OSP administration, and several were on nonsteroidal anti-inflammatory drugs or diuretics. Many of them were left with CKD: at follow-up roughly 17 mo after OSP exposure, the mean serum creatinine was 2.4, and 4 of 21 were dialysis dependent. Additional biopsy-proven reports of phosphate nephropathy have appeared, including one in which a patient had two kidney biopsies, the first of which showed membranous nephropathy and the second performed two months after the first, after an OSP prep, which showed membranous nephropathy plus de novo calcium-phosphate deposits not present on the first biopsy (50–53).
Another patient with biopsy-proven phosphate nephropathy after OSP presented with acute visual loss from uremic optic neuropathy (54).

Kidney Injury after OSP: Observational Studies

Although dramatic, the biopsy-based case series of Markowitz et al. (48,49) and others leave unanswered important questions about the mechanisms by which OSP might result in phosphate nephropathy and do not address the risk of this complication in a population of patients who receive OSP. Recently, several observational studies of patients with preserved renal function who underwent bowel preparation have appeared and have reached conflicting conclusions about OSP and the risk of kidney injury (55–58).

Using a U.S. Department of Defense data system, Hurst et al. studied 9799 patients who underwent colonoscopy and identified 114 who had a >50% increase in baseline creatinine after the procedure (56). After adjustment for confounders in a multivariate analysis, the use of OSP was associated with increased risk of renal failure (odds ratio = 2.35). This association became stronger when the authors limited their analysis to patients with more severe kidney injury (defined as a doubling of serum creatinine). Older age was an independent risk factor for kidney injury from OSP. At follow-up an average of 8 months after the colonoscopy, the mean creatinine among the group with kidney injury (1.38) was below the peak value (1.78) but remained substantially above the preprocedure value (0.98), supporting the hypothesis that OSP causes CKD in addition to AKI. In the same issue, Brunelli et al. reported a case-control study using data from a cohort of 2237 patients who underwent colonoscopy at hospitals associated with the University of Pennsylvania (55). Using a definition of kidney injury that was somewhat less restrictive than that of Hurst et al. (56), the authors identified 116 patients with kidney injury after colonoscopy but were unable to find any association with OSP use. Patients who received OSP preps and were taking ACE inhibitors or angiotensin receptor blockers did appear to be at increased risk for kidney injury compared with those who were not.

Investigators from the Degge Group, a drug safety consulting firm based in Arlington, VA, working with collaborators and data from the Henry Ford Health System and grant support from the C.B. Fleet Company, studied 2352 patients with baseline normal renal function who underwent colonoscopy with OSP or PEG-ELS preparation and had creatinine determinations within 6 months of the procedure; 3.8% of OSP recipients and 3.3% of PEG-ELS recipients developed kidney injury, defined by a reduction in estimated glomerular filtration rate (GFR) to <60 ml/min. The adjusted odds ratio for GFR decline was 1.14 in the OSP group relative to PEG-ELS, but this difference was not statistically significant (confidence interval, 0.55 to 2.39). The authors concluded that the risk of renal impairment is similar with both preparations.

Khurana et al., who had previously reported a series of 12 cases of clinically diagnosed cases of phosphate nephropathy, subsequently reported a retrospective case-control study and found a statistically significant decline in GFR 6 months after OSP exposure (58,59). ACE and ARB use and diabetes mellitus were again identified as risk factors. Like the Hurst et al. study discussed earlier (56), this study also appears to identify a subset of patients who do not develop clinically manifest AKI but nonetheless end up with CKD as a result of the exposure. Of note, the control group included patients who had not received colonoscopy as well as patients who had not developed renal failure after colonoscopy. Selecting a control group by excluding patients with the outcome of interest will inevitably bias a study toward a positive result.

In conclusion, two of these four observational studies support an association between OSP and kidney injury and two do not. The reasons for these different results may lie in study methodologies, including the different definitions of kidney injury as well as the interval after colonoscopy at which the renal function was assessed. Selection of patients from different eras may have also influenced the results: whereas Hurst et al. (56) studied colonoscopy procedures conducted from 2002 through 2006, Brunelli et al. (55) assessed procedures from 2004 and 2005, many of which were performed coincident with or after the Markowitz et al. report (48), which might have biased providers against OSP. In each of these studies, patients who receive PEG-ELS appear at baseline to be at higher risk for kidney injury than patients who receive OSP, reflecting the widespread (although not universal) awareness among providers concerning the potential risk of OSP; thus, residual confounding or bias if present would skew the results in favor of OSP safety. Clearly, further studies are required to precisely determine the incidence of both AKI and CKD after OSP preparation. Randomized trials could eliminate the problem of residual confounding but would be limited to low-risk patients, which might not reflect the patients exposed to OSP in actual clinical practice. Studies that report 6- to 12-month follow-up of patients who develop metabolic complications after PEG-ELS are also absent from the literature. Further work is also required to define how and when CKD can complicate OSP in the absence of AKI, which will require stricter definition of the two entities. As discussed below, different pathophysiologic processes might explain these different clinical presentations.

Mechanism of Kidney Injury from OSP: Nephrocalcinosis

As is typical in clinical nephrology, the AKI associated with OSP is likely multifactorial. Advanced age and ACE/ARB use have been identified in both case series and population studies as risk factors. Additional putative risk factors, which have not been rigorously defined, are shown in Table 1 and include acute or CKD or the presence of a kidney transplant, excessive or repeated dosing, retention of OSP resulting from poor bowel motility or colitis, female gender, true or effective volume depletion from congestive heart failure or cirrhosis, a history of hypertension or diabetes, and diuretic, lithium, or nonsteroidal anti-inflammatory drug use (31,33,49,60). Although these factors are familiar to nephrologists as risks for prerenal azotemia and acute tubular injury, a unique aspect of kidney injury associated with OSP is the deposition of calcium-phosphate
calcium oxalates. Calcium phosphate crystals are not birefringent upon examination under polarized light. Hypercalciuria is a well-established risk factor for calcium crystal deposition, but nephrocalcinosis can occur in the setting of normal calcium excretion, particularly in the presence of primary or secondary hyperoxaluria (63). Patients with primary hyperoxaluria over-produce oxalate due to inherited enzyme defects and develop severe nephrocalcinosis and nephrolithiasis (64). Secondary hyperoxaluria in patients with inflammatory bowel disease or malabsorption is also a common cause of nephrocalcinosis and may on occasion be associated with atherosclerosis due to calcium-oxalate deposition in the vasculature. Recently, calcium-oxalate nephropathy has been reported in a patient taking orlistat, an over-the-counter medication that inhibits intestinal lipid metabolism and results in secondary hyperoxaluria (65). Ethylene glycol is metabolized to oxalate and can also result in kidney injury due to calcium-oxalate deposition.

 crystals, also known as nephrocalcinosis. It seems likely that mineral deposition is less reversible than the typical lesion of acute tubular necrosis and thus might predispose patients to the CKD observed by Markowitz et al. (48) and others.

Nephrocalcinosis is a tubulointerstitial nephropathy that either reflects a primary pathophysiologic process or results from severe tissue injury of any cause, so-called “dystrophic” calcification. In mild cases, plain x-rays may reveal nephrocalcinosis as small deposits of calcium salts in the calyces, resembling “pictures of the night sky” (61). Although CT scanning is the most sensitive imaging technique to detect nephrocalcinosis, severe cortical calcifications detected by kidneys, ureters, and bladder (KUB) plain film weeks or months after an ischemic kidney injury indicate renal cortical necrosis and is associated with nonrecovery of renal function (62). In cases of hyperparathyroidism, calcium salts are typically found along medullary tubular basement membranes, as concretions within tubules, and in the interstitium (62). The calcium-phosphate deposits seen after OSP are found primarily in the tubular lumens and the cytoplasm of tubular epithelial cells, with rare interstitial deposits as well (48). Paradoxically, many patients with nephrocalcinosis detected radiographically may have minimally impaired renal function, whereas nephrocalcinosis seen in association with OSP use, which can only be detected by kidney biopsy, may be associated with acute and CKD.

Nephrocalcinosis may be diagnosed incidentally or may present like any tubulointerstitial nephropathy, with low-grade proteinuria (<1 g/d), a bland urine sediment, or an unexplained rise in the serum creatinine. The patient may have a history of nephrolithiasis or renal colic. Hypercalcemia and hypercalciuria associated with hyperparathyroidism or malignancy are the most common causes, whereas granulomatous disease, immobilization, or vitamin D intoxication may on occasion be implicated. Through a variety of mechanisms, distal renal tubular acidosis may cause nephrocalcinosis, although nephrocalcinosis itself may cause distal acidification defects, thus confusing the association. Particularly in children, medullary sponge kidney and nephrocalcinosis may coexist.

Nephrocalcinosis occurs when calcium precipitates in conjunction with either oxalate or phosphate. The phosphates in calcium-phosphate deposits are detected in paraffin sections by the von Kossa stain (Figure 2). This stain does not detect pure calcium oxalates. Calcium phosphate crystals are not birefringent, whereas calcium oxalate crystals are birefringent upon examination under polarized light. Hypercalciuria is a well-established risk factor for calcium crystal deposition, but nephrocalcinosis can occur in the setting of normal calcium excretion, particularly in the presence of primary or secondary hyperoxaluria (63). Patients with primary hyperoxaluria over-produce oxalate due to inherited enzyme defects and develop severe nephrocalcinosis and nephrolithiasis (64). Secondary hyperoxaluria in patients with inflammatory bowel disease or malabsorption is also a common cause of nephrocalcinosis and may on occasion be associated with atherosclerosis due to calcium-oxalate deposition in the vasculature. Recently, calcium-oxalate nephropathy has been reported in a patient taking orlistat, an over-the-counter medication that inhibits intestinal lipid metabolism and results in secondary hyperoxaluria (65). Ethylene glycol is metabolized to oxalate and can also result in kidney injury due to calcium-oxalate deposition.
In many cases, the initial event in the development of both nephrocalcinosis and nephrolithiasis may be the formation of calcium-phosphate deposits in the thin limb of Henle, called “Ran- dall’s plaques,” which form largely due to supersaturation of calcium and phosphate in that portion of the tubule (66,67). When these plaques rupture into the urinary space, they serve as a nidus for calcium-oxide crystallization, and nephrocalcinosis results when the urothelium overgrows and encapsulates the crystals (63,68). The observation that most calcium-oxide stones contain some calcium-phosphate supports this mechanism (61,66).

Throughout much of the kidney tubule, calcium and phosphate exist in an “unstable compromise” of ionic supersaturation that is maintained by inhibitors, such as citrate, Tamm-Horsfall protein, and pyrophosphate (69). Once calcium-phosphate crystals form, urinary crystals of any type can promote crystal growth, which explains why treatment of hyperuricemia with allopurinol can prevent calcium stone formation (70). Despite these mechanistic similarities, clinical experience shows that some patients with nephrolithiasis have no nephrocalcinosis whereas other patients display the opposite pattern.

The deposition of calcium oxalate and calcium phosphate can be viewed within the broader context of renal crystal deposition. Under even normal conditions, the progressive concentration of urine through the removal of water and the extremes of urinary pH can create an environment conducive to crystal formation (66). Uric acid and cystine crystals form most readily in an acid urine, whereas alkaline conditions favor calcium-phosphate crystals. In contrast, calcium oxalate crystal formation is pH independent. Medications that are concentrated in the urine can precipitate and contribute to kidney injury. Well-recognized offenders include acyclovir, foscarinet, methotrex- ate, the sulfonamides, and indinavir (71). Recently, the deposition in kidney and other tissues of the cation gadolinium in association with phosphate and other anions has been implicated in the pathogenesis of nephrogenic systemic fibrosis (72). Gadolinium deposits are basophilic on hematoxylin and eosin staining and may be confused with nephrocalcinosis (73).

Hyperphosphaturia and Kidney Injury

Just as nephrocalcinosis can result from hyperoxaluria and the subsequent deposition of calcium-oxalate crystals, hyperphosphatemia and hyperphosphaturia can cause nephrocalcinosis and AKI through the deposition of calcium-phosphate crystals. This phenomenon, which has been described in diverse clinical settings as well as in animal models of hyperphosphaturia, lends support to the hypothesis that phosphaturia after OSP administration underlies the development of phosphate nephropathy.

In the 1930s and again in the 1960s, the use of phosphate to treat symptomatic hypercalcemia of varying causes was complicated by metastatic calcifications and AKI (74–78). Extraskel-etal calcifications were occasionally demonstrated on plain x-rays and slit-lamp examination (79). Clinical investigations confirmed that phosphate administration lowered serum cal- cium primarily through Ca-Pi deposition (80,81).

In another example of exogenous phosphate therapy driving calcium-phosphate deposition in the kidney, patients with X-linked hypophosphatemic rickets (XLH) treated with phos-
drocytes and macrophages, respectively. Given the ability of specific TLRs to recognize calcium crystals and the expression of a variety of TLRs in the adult kidney, we speculate that intraluminal calcium-phosphate crystal formation after OSP leads to recognition by specific epithelial TLRs with activation of the innate immune response (90,91). Persistence of these crystals could result in chronic inflammation with extracellular matrix deposition and interstitial fibrosis (92). Clearly, the cellular and molecular mechanisms of OSPS-mediated renal fibrosis require investigation.

An intriguing correlation between hyperphosphatemia, crystal deposition, and tissue fibrosis has been suggested in the pathogenesis of nephrogenic systemic fibrosis (72). Gadolinium-based contrast exposure is strongly implicated in the development of NSF, and patients developing this debilitating condition have Gd$^{3+}$ tissue deposition (93). Excess serum phosphate may bind free Gd$^{3+}$ with subsequent tissue deposition. Gd$^{3+}$-phosphate complexes can be demonstrated in tissues of patients with NSF (72). The subsequent process of Gd$^{3+}$-crystal-induced fibrosis may be similar to that evoked by calcium phosphate crystals, with phagocytosis of crystals into resident phagocytes (or perhaps epithelial cells) mediated by pattern recognition receptors, ultimately activating the innate immune response and causing a chronic inflammatory and pro-fibrotic process.

A Lower Dose Product and Remaining Questions

In response to the reports of phosphate nephropathy as well as warnings from government agencies concerning the use of OSP, the largest manufacturer of OSP products, the C.B. Fleet Company, discontinued the sale of the 90-ml OSP preparation (45 ml + 45 ml) and substituted a 75-ml dose product (45 ml + 30 ml), which reportedly has equal efficacy (94–96). Recommendations from the company continue to emphasize the importance of separating the two doses by an interval approaching 12 h and of maintaining adequate hydration before, during, and after OSP bowel preparation (97).

Although lower-dose OSP preparations appear to cause more modest elevations in serum phosphate, it is unknown whether they are safer than standard dose preparations. Similarly, it is unknown whether optimal oral hydration can replace OSP-associated losses while maintaining normal electrolyte levels and preventing phosphate nephropathy. Recommendations for volume repletion with OSP preps vary from 0.7 to 2.2 L (Fleet currently recommends a “minimum” of 72 oz), but the optimal amount may exceed 3.7 L (98,99). Even carefully selected patients who were given explicit instructions for oral hydration and were studied in the setting of a clinical trial lost an average of 2.3 lbs of body weight after sodium phosphate bowel prep, although weight loss has also been observed with the combination of PEG-ELS + bisacodyl (4,94). In addition, the benefits of increased water intake need to be balanced against the risk of hyponatremia (23,25,26). It is also unknown whether water is adequate for oral hydration or whether electrolyte-containing oral rehydration solutions would be safer (97).

Other significant gaps exist in our knowledge of OSP-associated kidney injury. Although some estimate that phosphate nephropathy may affect as many as 1400 to 7000 Americans each year, prospectively collected data defining the true incidence of phosphate nephropathy are needed (100). Such data would also provide better information concerning putative risk factors, such as hypertension, diabetes, female gender, and renin-angiotensin blockade. The role of OSP-induced kidney injury in the development CKD, in the absence of diagnosed AKI, needs investigation, as does the role of parathyroid hormone and vitamin D status as potential risk factors (101).

Conclusion

Adequate bowel preparation is mandatory for colorectal cancer screening, and clinicians selecting bowel-cleansing agents must consider the potential metabolic consequences of OSP and PEG-ELS use. Although the ethical imperative to “do no harm” and the large and growing number of colonoscopies performed each year compel physicians to favor bowel purgatives that pass a very high standard of safety, the renal risks posed by OSP raised in this article need not change clinical practice in low-risk patients. Table 2 summarizes our suggested absolute

<table>
<thead>
<tr>
<th>Table 2. Suggested contraindications to oral sodium phosphate administration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Absolute contraindications</strong></td>
</tr>
<tr>
<td>Estimated glomerular filtration rate &lt;60 ml/min</td>
</tr>
<tr>
<td>Significant kidney disease with preserved GFR (e.g., nephrotic syndrome)</td>
</tr>
<tr>
<td>Preexisting hyperphosphatemia of any cause</td>
</tr>
<tr>
<td>Clinically significant congestive heart failure or cardiomyopathy</td>
</tr>
<tr>
<td>Clinically significant cirrhosis and/or ascites</td>
</tr>
<tr>
<td>Gastrointestinal disease, as detailed on package label including obstruction, megacolon, perforation, ileus, inflammatory bowel disease</td>
</tr>
<tr>
<td>Hypersensitivity to the ingredients</td>
</tr>
<tr>
<td><strong>Relative contraindications</strong></td>
</tr>
<tr>
<td>Age &lt;18 or &gt;60 to 70 or clinically significant debilitation</td>
</tr>
<tr>
<td>Use of diuretics, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, or nonsteroidal anti-inflammatory drugs, especially if in combination</td>
</tr>
<tr>
<td>Dehydration or risk for dehydration (e.g., nausea, vomiting, diarrhea, low salt diet, inability to take adequate oral fluids).</td>
</tr>
<tr>
<td>Uncorrected electrolyte abnormalities</td>
</tr>
<tr>
<td>Cardiac disease as detailed on package labeling, including recent MI, prolonged QT interval, or drugs that prolong interval, arrhythmia, unstable angina</td>
</tr>
<tr>
<td>Pregnancy or nursing a child, as per package labeling</td>
</tr>
</tbody>
</table>
and relative contraindications for OSP prescription. Multiple causative factors may contribute to kidney injury after bowel preparation, especially in patients with impaired intrarenal hemodynamics at baseline or volume depletion. Phosphate nephrotoxicity is an important, although probably rare, cause of acute and chronic kidney injury after OSP use, particularly when prescribed to well-selected subjects. The risk of phosphate nephrotoxicity from OSP may be mitigated by adequate volume repletion and the use of the minimal effective dose. Caution is warranted when any bowel preparative is administered to medically fragile patients, particularly those on maintenance hemodialysis. The ongoing use of OSP preps in high-risk patients, despite literally hundreds of published adverse reactions over a decade or more, underscores the limitations of manufacturers’ recommendations and the extant medical literature in improving prescribing safety (57).

Disclosures
S.O.T. serves on the boards of directors of Merck & Co., Inc. and Charles River Laboratories, Inc.

References
24. Tan HL, Liew QY, Loo S, Hawkins R: Severe hyperphosphataemia and associated electrolyte and metabolic de-
rangement following the administration of sodium phosphate for bowel preparation. *Anesthesia* 57: 478–483, 2002


