Bedside Emergency Department Ultrasonography plus Radiography of the Kidneys, Ureters, and Bladder vs Intravenous Pyelography in the Evaluation of Suspected Ureteral Colic

SEAN O. HENDERSON, MD, RICHARD J. HOFFNER, MD, JODI L. ARAGONA, MD, DIANE E. GROTH, BS, VICTOR I. ESEKOGWU, MD, DENNIS CHAN, MD

Abstract. **Objective:** To determine the role of bedside renal ultrasonography (US) and plain radiography of the kidneys, ureters, and bladder (KUB) as the initial investigative modality for those patients presenting to the ED with unilateral flank pain and hematuria. The hypothesis was that the renal US + KUB may obviate the need for emergent IV pyelography (IVP) in a majority of patients. **Methods:** Prospective study over an 8-month period of all consecutive adult patients between the ages of 18 and 65 years presenting with unilateral flank pain and hematuria to the ED at LAC + USC Medical Center. Patients received KUB followed by a 500-mL bolus of normal saline. Bedside US was then performed by emergency physicians (EPs). Hydronephrosis of the kidney was graded as mild, moderate, or severe. All patients then underwent IVP. The results of the bedside US + KUB were then compared with those of IVP (the criterion standard). **Results:** Of a total of 139 eligible patients, 108 were enrolled. The combination of US and KUB correctly identified pathology consistent with nephroureterolithiasis with a sensitivity of 97.1% (95% CI = 93.1–100%) when compared with IVP. The KUB + US results were falsely positive in 16 patients, resulting in a specificity of 58.9% (95% CI = 43.5–74.3%). The positive predictive value of the combined modality was 80.7%, the negative predictive value was 92.0%, and the overall accuracy was 83.3%. **Conclusion:** The bedside US + KUB has a high sensitivity and can be performed rapidly at the bedside by the EP when compared with IVP. This combined modality is an effective screening tool in the initial evaluation of ureteral colic. **Key words:** renal colic; renal ultrasound; nephroureterolithiasis; ureteral colic; KUB; radiography. ACADEMIC EMERGENCY MEDICINE 1998; 5:666–671

EMERGENT IV pyelography (IVP) has traditionally been the recommended modality for evaluating patients with acute unilateral flank pain and hematuria. IVP has a number of limitations and is not recommended in patients with renal insufficiency, those with a history of past allergic reactions to contrast material, or patients who are pregnant. Performing IVP is time-consuming, causing an increased length of stay in the ED, and involves other personnel, some of whom may not be immediately available (radiologist, technician). Despite these issues, IVP continues to be described as the criterion standard in the initial evaluation of ureteral colic.[1]

Ultrasonography (US) is a noninvasive, safe, and reliable imaging modality that can be performed at the bedside. While the use of US by the emergency physician (EP) has recently been advocated in the assessment of a wide variety of clinical entities,[2–6] little has been reported regarding the use of this modality in the assessment of nephroureterolithiasis. Multiple reports in the urologic and radiologic literature indicate that US is a safe and noninvasive method of screening for renal obstruction.[7–12] Its bedside use by EPs makes it an inexpensive and rapid alternative to IVP.

We undertook a prospective trial to determine the efficacy of plain radiography of the kidneys, ureters, and bladder (KUB) plus bedside US by an EP as an initial screening tool in the evaluation of ureteral colic. We hypothesized that this combined modality, in conjunction with the clinical history, would be a sensitive, accurate method of evaluating patients with nephroureterolithiasis, and could supplant emergent IVP.

From the Department of Emergency Medicine, University of Southern California School of Medicine, Los Angeles, CA (SOH, DEG, DC); and the Department of Emergency Medicine, LAC + USC Medical Center, Los Angeles, CA (RJH, JLA, VIE). Current affiliation: Department of Emergency Medicine, University of California, San Diego, San Diego, CA (DC).
Received August 25, 1997; revision received November 17, 1997; accepted December 3, 1997. Presented at the SAEM annual meeting, Washington, DC, May 1997.
Address for correspondence and reprints: Sean O. Henderson, MD, Department of Emergency Medicine, University of Southern California School of Medicine, LAC + USC Medical Center, Unit #1, Room 1011, 1200 North State Street, Los Angeles, CA 90033. Fax: 213-226-8044; e-mail: sohender@hsc.usc.edu

METHODS

Study Design. This prospective study had the approval of our facility's institutional review board and was conducted between July 1996 and February 1997. Consecutive patients presenting to the ED at our institution with symptoms consistent with ureteral colic were evaluated for inclusion. All patients gave informed consent prior to enrollment in the study.

Setting and Population. The study was performed at the Los Angeles County + University of Southern California Medical Center, a university-affiliated ED with approximately 150,000 visits per year. Patients eligible for inclusion were between 18 and 65 years of age and presented with symptoms of ureteral colic (e.g., unilateral flank pain with radiation to the groin or lower abdomen and either gross or microscopic hematuria). Patients who were pregnant, had a history of allergy to contrast material, or were found to have a creatinine level >1.8 mg/dL were excluded.

Experimental Protocol. As is the practice at our institution in cases of suspected ureteral colic, routine urinalysis, complete blood count (CBC), electrolytes, BUN, and creatinine were determined and appropriate analgesia was administered. In addition, each of our patients received an IV bolus of 500 mL of normal saline, since most authors describe the need for initial rehydration of the patient prior to the sonographic examination.[8,13,14]

A KUB was then obtained for all patients. A positive result was defined as a calcific density in the region of the renal collecting system or ureter on the same side as the presenting flank pain. The US study was performed with a real-time scanner (ATL Ultramark 4 PLUS, Advanced Technologies Laboratories, Bothell, WA) using a 3.5-MHz probe. The bedside scans were performed by the emergency medicine attending staff or residents (PGY2, 3, or 4) on duty at the time of patient presentation. Levels of previous US experience varied, but all participating clinicians had received standardized didactic and practical training on US technique. All US studies were recorded on a VHS recorder for later overread. Hard copies of all studies were also kept on file.

With the patient in the prone position, both kidneys were visualized by US in the longitudinal and transverse axes. If hydronephrosis was seen on US or calcification was seen on KUB, the combined US and KUB modality was considered positive.

The clinical history and KUB and US findings were interpreted and a prospective diagnosis was made and recorded by the treating EP. IVP was then performed on all patients. A 100-mL IV bolus of ionic contrast material was given followed by radiographs at 1, 5, 10, 15, and 20 minutes, as well as post-void and delayed films if indicated. The completed IVP was initially reviewed by radiology housestaff without any knowledge of the ED ultrasound results.

Measurements. The degree of calyceal dilatation detected by US was graded subjectively as none, mild, moderate, or severe. "None" was defined as a homogeneous central collecting system, "mild" as a slight separation of the collecting system, with central sonolucencies, "moderate" as further dilatation with a central rounded lucency, and "severe" as a replacement of the major portion of the kidney with a central sonolucency. Standardized reference examples were developed in conjunction with radiology and were posted on the ultrasound machine (Fig. 1). The first 20% of the US studies were overread by radiology, with 100% concordance.

Positive findings on IVP believed to be consistent with nephroureterolithiasis were: unilateral hydronephrosis of the renal pelvis, hydroureters, delayed nephrograms, calcifications within the renal collecting system, and filling defects within the ureters. All IVPs were later overread by staff radiologists; these final readings were considered the final radiographic diagnosis of the patient.

Each patient was individually assessed for possible admission to the hospital. Admission criteria included fever >101°F, evidence of an infected stone, delayed excretion of the affected kidney at 2 hours post-IVP, intractable pain despite appropriate analgesia, and inability to tolerate oral fluids. Those patients released home were given a follow-up appointment with an urologist within 2 weeks. All hospital and clinic records were reviewed at least 1 month after the initial presentation to determine the patient's final disposition and the occurrence of delayed complications.

Data Analysis. The final readings of the US + KUB and the IVP were compared. The sensitivity, specificity, positive predictive value, and negative predictive value as well as the overall accuracy were calculated with the 95% confidence intervals derived from the normal approximation of proportions.

RESULTS

Of the 139 patients eligible for the study, 108 completed the study protocol (77%). Sixty-two (57%) of the study subjects were male and 46 (43%) were female. The US studies documented 43 cases of mild hydronephrosis, 23 cases of moderate hydronephrosis, and 7 cases of severe hydronephrosis. No technical difficulties were encountered with the

US technology. Both kidneys, when present, were easily visualized. Evidence of calcifications was detected in the KUB examinations of 49 patients. Of the 69 cases of nephroureterolithiasis documented on IVP, the US + KUB combined modality recognized 67 cases, resulting in a sensitivity of 97.1% (95% CI = 93.1–100%) (Table 1).

Of the 39 nonobstructed kidneys demonstrated by IVP, 23 were correctly diagnosed as normal on US + KUB, leading to a specificity of 58.9% (95% CI = 43.5–74.3%). Of the remaining 16 patients, 1 had pyelonephritis, 4 had calcifications on KUB that were later found to be outside the collecting system on IVP, 1 had a previously documented chronic fluid collection in the upper pole of her kidney, and 1 with mild bilateral hydronephrosis had urinary retention and chronic microhematuria. The remaining 9 patients had normal IVPs and US examinations that were incorrectly interpreted as positive at the bedside.

Ureteral stents were placed in 3 patients thought to have total obstruction. Two of these patients were admitted from the ED to the urology service for findings of delayed excretion on IVP and intractable pain. The other patient was released home and returned 1 week later with persistent pain. The IVP obtained on this second presentation revealed a calculus with continued obstruction, necessitating stent placement.

DISCUSSION

Many options exist for the emergency management of patients with the presumptive diagnosis of nephroureterolithiasis. The patient may be released home with no testing beyond a urinalysis and CBC. IVP may be done to assess the patient's renal architecture and function. The patient may receive other diagnostic testing such as US, plain radiographs, or a CT scan. Most clinicians are not satisfied with the first option. A recent study demonstrated that clinical judgment alone does not sufficiently predict the presence of nephroureterolithiasis.[1] However, IVP costs approximately $300–$600 in hospitals surrounding our county facility, places the patient at a small but definite risk for anaphylaxis, takes time to perform, and involves personnel outside the ED (technician, radiologist).

Many studies have been performed over the past 2 decades by urologists and radiologists to determine the role of US in the acute evaluation of

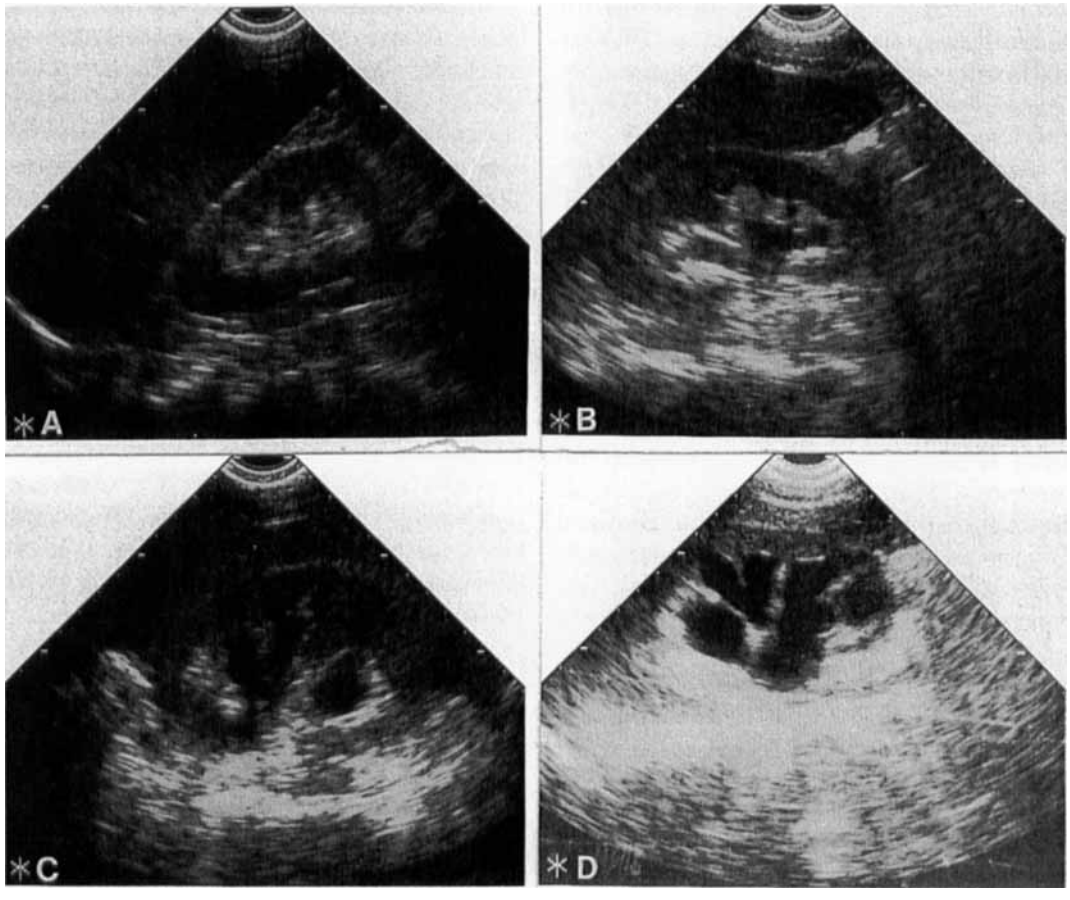

Figure 1. Examples of normal kidney (**A**), mild hydronephrosis (**B**), moderate hydronephrosis (**C**), and severe hydronephrosis (**D**).

nephroureterolithiasis. The results have been controversial and not well defined.[12,15,16] US is inexpensive and readily available at the bedside. However, it has certain limitations. Stones <4 mm are not visualized, and little information regarding renal function is provided. Further, dilatation of the collecting system seen with US may be due to obstruction from noncalculous sources, or may be nonobstructive, causing "false-positive" scans.

Although US cannot easily detect calcifications within the mid-ureter, its ability to demonstrate hydronephrosis is well documented.[8,13,14] The hydronephrosis that may occur in nephroureterolithiasis depends on the size and location of the stone, the length of time the obstruction has been present, and whether the obstruction is partial or complete. Despite a high false-positive rate (26%), Ellenbogen et al. found that US had a 98% sensitivity in detecting hydronephrosis when compared with IVP and appeared to be a good screening method.[17] Erwin et al. also found unilateral hydronephrosis or calculus on US in all 18 patients (100% sensitivity) confirmed to have nephroureterolithiasis.[13] Sinclair et al. found that IVP and US were almost equal in sensitivity in detecting nephroureterolithiasis (90% and 85%, respectively).[14] To achieve this level of sensitivity, however, patient hydration with at least 500 mL of fluid was necessary.[8,14] Since many patients presenting with nephrolithiasis have been experiencing emesis, fluid hydration will help return them to euvolemia, and will also provide the appropriate urine volume needed for bladder distention for the visualization of ureterovesicular junction (UVJ) calculi. Studies of US evaluation for hydronephrosis in nonhydrated patients have reported a detection rate as low as 35%, while studies providing hydration for patients suffering from nephroureterolithiasis describe an US detection rate of 90–98%.[8]

Despite these findings, other studies have been contradictory and suggest that US cannot replace IVP as the initial investigation in the evaluation of nephroureterolithiasis.[10,16,18] The difficulty encountered in attempting to visualize calcifications on US, at sites other than the UVJ and ureteropelvic junction, has prompted the addition of KUB as a screening tool. In a retrospective study, Hill et al. found that all of the obstructing stones missed by sonography were calcified and evident on the initial KUB.[12] The efficacy of the combined modality of US + KUB has also been described by Dalla Palma et al., who reported a sensitivity of the combination of US + KUB in the acute evaluation of ureteral colic similar to ours (95%).[8] Their low specificity (67%) is also similar to our results.

Our study is the first to use the bedside renal US performed solely by EPs in the initial evaluation of nephroureterolithiasis and duplicates findings described in the radiologic[8,13,17] and urologic[10,11,18] literature. We believed that hydronephrosis was the finding that could be most easily identified on both US and IVP. We found that US alone identified 61 of 63 cases of hydronephrosis subsequently demonstrated on IVP (97%). The overall sensitivity of US compared with any abnormality on IVP suggestive of nephroureterolithiasis was 90% (61 of 68).

TABLE 1. Results for the 108 Patients Enrolled*

	IVP	
US + KUB	Positive	Negative
Positive	67	16
Negative	2	23

*US + KUB = ultrasonography plus plain radiography of the kidneys, ureters, and bladder; IVP = IV pyelography. Negative predictive value = 92.0%; positive predictive value = 80.7%; overall accuracy = 83.3%.

The low specificity (57%) of our study is similar to that of earlier studies that also demonstrated a high false-positive rate,[8] and is consistent with the belief that the US + KUB combination is an effective screening modality for nephroureterolithiasis. Conditions that may produce this high incidence of false positives are varied, and include renal cystic disease, inflammatory conditions such as pyelonephritis, overdistention of the bladder, vesicoureteral reflux, and calcifications seen on KUB that are outside the renal collecting system.[8–10] Another possible explanation of our high rate of false positives could be the elapsed times between US and IVP. It is feasible that some patients may have passed a kidney stone and decompressed the renal collecting system while awaiting IVP. All patients with false-positive results were later referred to an urologist for follow-up.

Our false-negative rate of 1.8% suggests that the combined modality is a reliable method for excluding obstruction due to nephroureterolithiasis. The 2 patients with false-negative results both had delayed nephrographies and slightly full ureters, consistent with the recent passage of calculi. Neither had identifiable hydronephrosis or calculi.

The KUB, US, and IVP were all negative in 23 patients. Four of these patients were admitted with the diagnosis of pyelonephritis. The other patients were released home with the impression that they had had a small nonobstructing stone. All released patients met the criteria for release, and none were found to have other etiologies for their hematuria and flank pain. At outpatient follow-up, all but 1 patient reported resolution of their symptoms. No adverse sequelae were reported.

As the study progressed it became apparent that the amount of hydronephrosis on ultrasound did not correlate with either the degree of obstruction or the need for admission. Stents were placed in 2 patients emergently by urology when IVP demonstrated a high-grade obstruction; the bedside US of both patients demonstrated only mild hydronephrosis. Neither of these patients would have been released in any case, since the pain associated with their conditions was not easily controlled with analgesics administered in the ED. A third patient, whose IVP showed only a partial obstruction, returned a week later with intractable pain and was also treated with a stent. Finally, all 7 patients with severe hydronephrosis on US were found to have only partial obstructions on IVP.

LIMITATIONS AND FUTURE QUESTIONS

One limitation of our study was the variable amount of US training among the physicians involved with assessing the study participants. EPs must be comfortable with the use of the US technology before attempting to base patient diagnosis and disposition on US findings. Fortunately, there are an increasing number of emergency medicine training courses teaching the skills necessary to aid in the US evaluation of many traumatic and medical emergencies.

Another limitation of the study was that, on average, 4–5 patients per month either did not complete the study protocol or were not enrolled. In most cases these were patients who refused to wait the amount of time necessary to complete the study protocol. It is unclear whether these patients, if enrolled, would have altered our overall data.

The IVP contributes significant information that US cannot provide. It defines anatomy and function of the collecting system, as well as evidence of nephroureterolithiasis other than hydronephrosis, such as filling defects and localized dilation of the ureter. However in most cases, this more invasive test may be performed after the initial patient evaluation in the ED.

As EPs become more adept at US techniques, the use of Doppler US of the kidney may improve the accuracy of the bedside scan. Doppler US measures a resistive index, which increases in cases of outflow obstruction. Such data may allow clinicians to distinguish obstructed from nonobstructed hydronephrosis, thus reducing the false-positive rate.[19] Recently color Doppler has been used to visualize flow from the ureters into the bladder. While improving the specificity of the US study, the expertise needed and the tediousness of this modality make it currently impractical as a bedside test.[9]

CONCLUSION

The findings of our study suggest that emergent IVP may be replaced by the combination of bedside US + KUB in the ED for the initial evaluation of nephroureterolithiasis. This combined modality has a high sensitivity, can be performed with ease and rapidity within the ED, and reduces exposure to ionizing radiation and contrast material necessary for IVP. When US and KUB are used in conjunction with a good clinical history and examination, patients without evidence of obstruction may have their more invasive emergent IVP deferred. If the US and KUB are negative, other etiologies of the flank pain and hematuria must be considered.

The authors are grateful for the statistical support of Linda Chan, PhD, the radiologic support of Yuri Parisky, MD, and the editorial support of Laura E. Crocitto, MD, Department of Urology.

References

1. Wrenn K. Emergency intravenous pyelography in the setting of possible renal colic: is it indicated? Ann Emerg Med. 1995; 26:304–7.
2. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. Ann Emerg Med. 1997; 29:312–6.
3. Porter RS, Nester BA, Dalsey WC, et al. Use of ultrasound to determine need for laparotomy in trauma patients. Ann Emerg Med. 1997; 29:323–30.
4. Hilty WM, Hudson PA, Levitt MA, Hall JB. Real-time ultrasound-guided femoral vein catheterization during cardiopulmonary resuscitation. Ann Emerg Med. 1997; 29:331–7.
5. Durham B, Lane B, Burbridge L, Balasubramaniam S. Pelvic ultrasound performed by emergency physicians for the detection of ectopic pregnancies in complicated first-trimester pregnancies. Ann Emerg Med. 1997; 29:338–47.
6. Hill R, Conron R, Greissinger P, Heller M. Ultrasound for the detection of foreign bodies in human tissue. Ann Emerg Med. 1997; 29:353–6.
7. Haddad MC, Sharif HS, Abomelha MS, Riley PJ, Sammak BM, Shahed MS. Management of renal colic: redefining the role of the urogram. Radiology. 1992; 184:35–6.
8. Dalla Palma L, Stacul F, Bazzocchi M, Pagnan L, Festini G, Marega D. Ultrasonography and plain film versus intravenous urography in ureteric colic. Clin Radiol. 1993; 47:333–6.
9. Deyoe LA, Cronan JJ, Breslaw BH, Ridlen MS. New techniques of ultrasound and color Doppler in the prospective evaluation of acute renal obstruction. Do they replace the intravenous urogram? Abdom Imaging. 1995; 20:58–63.
10. Kuuliala IK, Niemi LK, Ala-Opas MY. Ultrasonography for diagnosis of obstructing ureteral calculus. Scand J Urol Nephrol. 1988; 22:275–7.
11. Juul N, Brons J, Torp-Pederson S, Fredfeldt K. Ultrasound versus Intravenous urography in the initial evaluation of patients with suspected obstructing urinary calculi. Scand J Urol Nephrol Suppl. 1991; 137:S45–S47.
12. Hill MC, Rich JI, Mardiat JG, Finder CA. Sonography vs excretory urography in acute flank pain. AJR Am J. Roentgenol. 1985; 144:1235–8.
13. Irwin BC, Carroll BA, Sommer FG. Renal colic: The role of ultrasound in initial evaluation. Radiology. 1984; 152:147–150.
14. Sinclair D, Wilson S, Toi A, Greenspan L. The evaluation of suspected renal colic: ultrasound scan versus excretory urography. Ann Emerg Med. 1989; 18:556–9.

15. Kamholtz RG, Cronan JJ, Dorfman GS. Obstruction and the minimally dilated renal collecting system: US evaluation. Radiology. 1989; 170:51–3.
16. Choyke PL. The urogram: are rumors of its death premature? Radiology. 1992; 184:33–6
17. Ellenbogen PH, Scheible FW, Talner LB, Leopold GR. Sensitivity of gray scale ultrasound in detecting urinary tract obstruction. AJR Am J Roentgenol. 1978; 130:731–3.
18. Amis ES, Cronan JJ, Pfister RC, Yoder IC. Ultrasonic inaccuracies in diagnosing renal obstruction. Urology. 1982; 19: 101–5.
19. Platt JF, Rubin JM, Ellis JH, DiPietro MA. Duplex Doppler US of the kidney: differentiation of obstructive from nonobstructive dilatation. Radiology. 1989; 171:515–7.

AEM Reviewer Erratum

Each December, *AEM* recognizes those individuals who have helped the journal through their efforts as reviewers during the preceding calendar year. The 1997 December issue of *AEM* contained a list of individuals who performed reviews on manuscripts received during 1996. Unfortunately, that list was incomplete. These reviewers were inadvertently left off the previous list. We apologize for this oversight, and want to officially recognize their contributions to and support of *AEM*.

Note that those who reviewed manuscripts received by the journal before or after calendar year 1996 will appear on lists for those specific years. Those initially overlooked reviewers who also serve on the *AEM* editorial board have been highlighted (*).

Richard V. Aghababian
Thomas Auble
Louis S. Binder*
Glenn Birnbaum
Jeffrey A. Brent
Charles G. Brown
Charles B. Cairns*
Rhodessa Capulong
Samuel T. Coleridge
Richard O. Cummins
Daniel F. Danzl
Eric Davis
Peter E. Doris
Steven C. Dronen*
Susan E. Dufel
Jim Ducharme
Timothy Erickson
Henry Farrar
Sue Fish
Douglas J. Floccare
Howard A. Freed
Anthony Ghidorzi
Daniel G. Hankins
Raymond Hart
Teresita M. Hogan
John M. Howell
Ken V. Iserson
Arthur Kellermann
Karl Kern
Robert K. Knopp
Rashmi Kothari
David A. Kramer
Michelle D. Leon
Louis J. Ling
O. John Ma
John MacKay
Ronald F. Maio
A. Roy Magnusson
Thomas G. Martin
Ricardo Martinez
John A. Marx*
James Matthews
Marc S. Nelson
James T. Niemann
Robert Norton
Elizabeth Orsay
Timothy Peterson
V. Gail Ray
Earl J. Reisdorff
John S. Rose
Walter A. Schrading
Dave Seaberg
Emil Skobeloff
Linda L. Spillane
Marc D. Squillante
J. Stephan Stapczynski
Thomas G. Stein
David A. Talan
Harold Thomas
Bruce Thompson
David R. Thomson
Matthew J. Walsh
Kevin R. Ward
William A. Watson
Robert L. Wears
Robert H. Woolard
Seth Wright
Arthur H. Yancey
Donald M. Yealy*
Leslie Zun