Risk Stratification for Renal Ultrasonography in the Evaluation of Acute Kidney Injury

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Abstract

Abstract Background Renal ultrasounds (RUS) are commonly ordered in hospitalized patients with acute kidney injury (AKI), however clinical risk prediction could be used to inform which patients require imaging to rule out hydronephrosis. While risk stratification frameworks have been described, the role of nephrology consultation as an additional driver of RUS ordering has not been comprehensively studied. Methods We performed a cross-sectional study of hospitalized adults at a large, tertiary, academic medical center with AKI who had a RUS ordered. Predictors were high-risk, medium-risk, or low-risk category based on an existing risk stratification framework and RUS recommended by a consulting nephrology service. Outcomes were presence of unilateral or bilateral hydronephrosis and incidental findings on RUS. Results Two hundred and eighty-one patients were included in the study cohort; 111 (40%), 76 (27%), and 94 (33%) patients were in the high-, medium-, and low-risk groups for hydronephrosis, respectively, based on the risk stratification framework. Thirty-five patients (12%) were found to have hydronephrosis, of whom 86% were captured in the high-risk group. A nephrology consult was involved in 168 (60%) patients and RUS was recommended by the nephrology service in 95 (57%) cases. Of the 95 patients recommended for a RUS, 9 patients (9%) had hydronephrosis. Among the patients with a nephrology consultation, 9 (56%) of the 16 total patients with hydronephrosis were recommended to obtain a RUS. Conclusions We further validated a risk stratification framework for hydronephrosis and found that nephrology consultation was an additional driver of RUS ordering, but predicted hydronephrosis less well than the risk stratification framework. Our decision framework strengthens the argument for the use of risk stratification to improve upon consultant recommendations, reduce incidental findings, and decrease RUS overuse.

Background

Renal ultrasounds (RUS) are commonly ordered in hospitalized patients with acute kidney injury (AKI) to rule out obstructive pathology.[1,2] However, pre-renal state and acute tubular necrosis (ATN) are far more likely causes of AKI, and obstructive uropathy causing hydronephrosis in patients with AKI is uncommon.[1,3-8] Furthermore, RUS detect incidental findings in the majority of patients, which may lead to additional imaging studies and testing, causing potential patient harm.[9] This has led some to question whether RUS for hospitalized AKI represents low-value care.[10]

Clinical risk prediction could be used to better inform which patients require imaging to rule out hydronephrosis.[7,8,11,12] A risk stratification framework to identify patients who are high- vs. low-risk for hydronephrosis have been described and validated, however is not widely used by primary teams or nephrology consultants.[9,13] Several factors may account for this: lack of knowledge of the framework, lack of workflow integration, and lack of assessment of harms of unnecessary imaging. We propose two additional drivers of RUS ordering that have not been well studied. First, nephrology consultants frequently recommend ordering RUS for hospitalized patients with AKI. Additionally, RUS may be ordered to evaluate the size and echogenicity of kidneys, rather than for solely ruling out hydronephrosis.

Assessing these additional drivers of RUS ordering is critical to understanding the role of risk stratification within a broader decision framework.

In this study, we validated the risk stratification framework for RUS ordering at our institution, and evaluated the role of nephrology consultation and the reason for exam as two additional drivers of RUS ordering. We examined two areas of potential harm from RUS overuse: incidental findings and additional workup. Understanding the drivers and sequelae of imaging is critical to demonstrate the value of clinical risk prediction and improve imaging stewardship.[14]

Methods

Study Design and Population

We performed a cross-sectional study of hospitalized adults at the Mount Sinai Hospital, an urban, 1134-bed academic medical center in New York, NY. We included all patients who (1) were admitted to the hospitalist service between June 9, 2013 and October 24, 2014, (2) experienced AKI (defined as Creatinine rise > 0.3), and (3) had a RUS ordered.

Risk Stratification

Our primary predictor was high-risk, medium-risk, or low-risk category for hydronephrosis based on the risk stratification framework developed by Licurse et al. (Supplemental Table 1).[9] The 7 criteria included in the framework are: a past history of hydronephrosis (4 points), and nonblack race, history of recurrent urinary tract infections (UTIs), diagnosis consistent with possible obstruction (abdominal or pelvic mass, benign prostatic hypertrophy, pelvic surgery, or neurogenic bladder) absence of exposure to inpatient nephrotoxic agents (aspirin > 81 mg, diuretics, angiotensin converting enzyme inhibitors, or vancomycin), absence of congestive heart failure, and/or absence of prerenal AKI (pressor use or sepsis) (1 point each). A total score of 4 or more points was classified as high-risk, 3 points as medium-risk, and 2 or fewer points as low-risk.[9] We performed an additional sensitivity analysis defining prerenal AKI as pressor use, sepsis, or history of hypotension defined as at least 2 consecutive blood pressure measurements below 80 mm Hg systolic or below 60 mm Hg diastolic. Additional predictors were presence of nephrology consultation and RUS recommended by the consulting service.

We performed a retrospective chart review to determine the presence or absence of each predictor, using only data available before the RUS was ordered. One author (JZ) performed the initial chart review, which was recorded in REDCap web-based application (Vanderbilt University). Another author (CG) independently reviewed a random selection of 10% of the charts with 96% agreement (Cohen's $\kappa = 0.913$, $p<0.00001$).

Outcomes

Our primary outcome was presence of unilateral or bilateral hydronephrosis. Secondary outcomes were incidental findings in the RUS radiology report, urologic procedure after RUS, and further imaging as a result of RUS. Incidental findings were classified into the following categories: increased echogenicity, simple cysts, complex cysts, renal atrophy or cortical thinning, non-obstructive nephrolithiasis, renal enlargement, renal mass, absence of kidney, obstructive nephrolithiasis, or other.[15] We also determined the reason for RUS ordering based on comments written in “Reason for exam” field in the RUS order.

Analysis

We described patient characteristics according to risk group for hydronephrosis, presence of nephrology consultation, and RUS recommended by consult service. We determined the prevalence of patients with hydronephrosis by risk group, nephrology consultation, and RUS recommendation. Chi-squared and analysis of variance tests were performed to determine if the proportion of patients in each group had different characteristics and risks of hydronephrosis. We calculated Pearson correlation coefficients to assess the correlation of factors in the risk score with hydronephrosis in our population. Our study was reviewed and approved by the Mount Sinai Institutional Review Board.

Results

Patient Demographics

Three hundred and twenty-two patients admitted to the hospitalist service received a RUS during the study period. Forty-one of these patients were not included because they did not have AKI. The final cohort included 281 patients. The mean age was 64 years, 57% of patients were male, and 63% were non-black (Table 1).

Risk Stratification Framework

There were 111 (40%), 76 (27%), and 94 (33%) patients in the high-, medium-, and low-risk groups for hydronephrosis, respectively. Patients in the high-risk group were less likely to be black (14% vs. 63%, $p<0.001$) and had higher creatinine levels at admission (4.2 vs 3.0 mg/dL, $p = 0.048$), compared with those in the low-risk group (Table 1). Thirty-five patients (12%) were found to have hydronephrosis, of whom 86% were captured in the high-risk group. Thirty of the high-risk patients (27%), one medium-risk patient (1%), and four of the low-risk patients (4%) were found to have hydronephrosis on RUS (Table 3). In terms of hydronephrosis severity, 53% of hydronephrosis was bilateral, 17% was severe, 39% moderate, and 56% mild. The prevalence of patients with hydronephrosis in the high-risk group was significantly higher compared to the combined medium- and low-risk group ($p<0.001$), which did not change after sensitivity analysis changing the definition of prerenal AKI (Supplemental Table 2). Five of the seven criteria were found to be correlated with increased risk of hydronephrosis at a statistically significant level in our population (Supplemental Table 3).

Nephrology Consultation

A nephrology consult was involved in 168 patients (60%). Patients with nephrology consultation had fewer recurrent UTIs (2 vs. 17%, $p<0.001$), higher creatinine levels at admission (4.7 vs 2.2 mg/dL, $p<0.001$), and higher baseline creatinine (2.1 vs 1.3 mg/dL, $p<0.001$) compared to those who did not have nephrology consultation (Table 2). RUS was recommended by the nephrology service in 95 of 168 cases (57%). Similarly, in the low-risk patient group, of the 61 low-risk patients (65%) who had a nephrology consult, 35 (57%) were recommended to obtain a RUS. Of the 95 patients recommended for a RUS, 9 patients (9%) had hydronephrosis. Among the patients with a nephrology consultation, 9 (56%) of the 16 total patients with hydronephrosis were recommended to obtain a RUS (Table 3).

Reason for Exam, Incidental Findings, and Additional Workup

The majority of RUS were ordered for AKI or renal failure (57%) or rule out hydronephrosis or obstruction (24%). Additional reasons for exam were oliguria or anuria, rule out pyelonephritis or abscess, evaluate for nephrolithiasis, and others (Table 4).

Only 37 patients (13%) had no abnormal findings on RUS; even within the low-risk group, only 16% of RUS were without abnormalities. The most common finding was increased echogenicity, which occurred in 195 patients (69%). One hundred and two (36%) had simple cysts and 34 (12%) had complex cysts (Table 5).

Four patients (1.4%) in the entire cohort underwent a urologic procedure, all of whom were in the high-risk group. Thirty-five patients (12%) received further imaging as a result of the RUS findings. Of the patients who underwent further imaging, 21 (60%), 11 (31%), and 3 (9%) were in the high-, medium-, and low-risk groups, respectively.

Discussion

We found that using a risk stratification framework to guide RUS ordering for hospitalized patients with AKI predicted 86% of episodes of hydronephrosis.[9,13] The majority (60%) of RUS were ordered on medium- or low-risk patients, while only 3% of these patients were found to have hydronephrosis.

Our analysis extends previous work by evaluating the role of nephrology consultation.[13] We found that risk stratification outperforms consultant recommendation, predicting 86% compared to 56% of hydronephrosis episodes. Previous analyses have found that appropriateness of certain diagnostic testing in AKI may increase when recommended by nephrology consultation rather than the primary team, however our findings did not support this for RUS.[4] When nephrology consultation was involved, RUS was recommended for the majority of patients, indicating that nephrology consultation serves as an additional driver of RUS ordering. Moreover, primary teams may preemptively order testing in anticipation of consultant recommendations, which further increases imaging utilization.

We found that the majority (87%) of RUS had incidental findings, which was similar to prior estimates.[10] Incidental findings pose challenges to physicians and patients, and can cause patient anxiety and

additional interventions.[16] While the majority of RUS had abnormalities, there was a low prevalence of urologic procedures and further imaging during the hospitalization. The high prevalence of incidental findings with RUS imaging raises ethical questions about when disclosure is warranted.[17]

The risk stratification framework studied was aimed specifically at identifying obstructive pathology on RUS in patients with AKI. To assess if consulting or primary teams requesting RUS were evaluating factors other than hydronephrosis, such as size or echogenicity of kidneys, we assessed reasons for RUS ordering listed in the “Reason for exam” field. The majority of RUS were ordered for AKI or renal failure (57%), without further explanation; only 3 RUS specifically listed the reason for exam as evaluating kidney size, echogenicity, or chronicity of kidney disease. Twenty-four percent of RUS listed rule out hydronephrosis or obstruction as the reason for exam. We were thus unable to reliably assess the clinical rationale for RUS ordering.

We present a framework to guide decision making for ordering RUS in hospitalized patients with AKI (Figure 1). Our framework incorporates review of prior imaging, risk stratification, consultation, costs and benefits of imaging, missed diagnosis, and harms of incidental findings.[18]

The major strength in our approach is the evaluation of consultation as a driver of RUS overuse and the detailed chart review used in our analysis. There are also limitations to our results. We conducted a single-site study and were unable to assess harms of incidental findings to patients. We did not assess all patients with AKI, only those with a RUS ordered. It is unknown whether RUS would have been obtained regardless of consultant recommendations. In some cases where RUS was obtained prior to nephrology consultation, it was unclear whether the consultant would have recommended the study based on the available documentation. Lastly, the definition used for prerenal AKI was use of pressors or history of sepsis, which may lack sensitivity for other clinically significant hypovolemic states.[9]

Conclusions

In conclusion, we further validated a risk stratification framework for hydronephrosis at our institution. We found nephrology consultation was an additional driver of RUS ordering, but predicted hydronephrosis less well than the risk stratification framework. There was a very high prevalence of incidental findings, but additional imaging and procedures were low. Our decision framework incorporates these considerations to strengthen the argument for the use of risk stratification to improve upon consultant recommendations, reduce incidental findings, and decrease RUS overuse.

Abbreviations

Renal ultrasound (RUS), acute kidney injury (AKI), urinary tract infections (UTIs)

Declarations

Ethics approval and consent to participate: This study was reviewed and approved by the Mount Sinai Institutional Review Board and Program for the Protection of Human Subjects (study number available upon request).

Consent for publication: Not applicable.

Availability of data and material: The datasets generated and analyzed during the current study are not publicly available as they contain protected health information, but summary statistics and statistical code are available from the corresponding author on reasonable request.

Competing interests: The authors have no conflicts of interest to disclose.

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Authors' contributions: Research idea and study design: SLT, HC, CG; data acquisition: JZ, CG; data analysis/interpretation: SLT, JZ; statistical analysis: SLT, JZ; supervision or mentorship: HC, CG. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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References

1. Waikar SS, Liu KD, Chertow GM. Diagnosis, epidemiology and outcomes of acute kidney injury. Clinical journal of the American Society of Nephrology : CJASN 2008;3:844-61.
2. Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. Journal of the American Society of Nephrology : JASN 2005;16:3365-70.
3. Young A, Crawford T, Pierre AS, et al. Renal ultrasound provides low utility in evaluating cardiac surgery associated acute kidney injury. Journal of cardiothoracic surgery 2017;12:75.

4. Leaf DE, Srivastava A, Zeng X, et al. Excessive diagnostic testing in acute kidney injury. BMC nephrology 2016;17:9.
5. Stuck KJ, White GM, Granke DS, Ellis JH, Weissfeld JL. Urinary obstruction in azotemic patients: detection by sonography. AJR American journal of roentgenology 1987;149:1191-3.
6. Ritchie WW, Vick CW, Glocheski SK, Cook DE. Evaluation of azotemic patients: diagnostic yield of initial US examination. Radiology 1988;167:245-7.
7. Podoll A, Walther C, Finkel K. Clinical utility of gray scale renal ultrasound in acute kidney injury. BMC nephrology 2013;14:188.
8. Remer EM, Papanicolaou N, Casalino DD, et al. ACR Appropriateness Criteria((R)) on renal failure. The American journal of medicine 2014;127:1041-8.e1.
9. Licurse A, Kim MC, Dziura J, et al. Renal ultrasonography in the evaluation of acute kidney injury: developing a risk stratification framework. Archives of internal medicine 2010;170:1900-7.
10. Gamss R, Stein MW, Rispoli JM, et al. What Is the Appropriate Use of Renal Sonography in an Inner-City Population With New-Onset Acute Kidney Injury? Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine 2015;34:1639-44.
11. Gottlieb RH, Weinberg EP, Rubens DJ, Monk RD, Grossman EB. Renal sonography: can it be used more selectively in the setting of an elevated serum creatinine level? American journal of kidney diseases : the official journal of the National Kidney Foundation 1997;29:362-7.
12. Liu KD, Chertow GM. Curbing the use of ultrasonography in the diagnosis of acute kidney injury: Penny wise or pound foolish?: Comment on "Renal ultrasonography in the evaluation of acute kidney injury". Archives of internal medicine 2010;170:1907-8.
13. Ip IK, Silveira PC, Alper EC, Benson CB, Khorasani R. External validation of risk stratification strategy in the use of renal ultrasonography in the evaluation of acute kidney injury. Journal of hospital medicine 2016;11:763-7.
14. Durand DJ, Lewin JS, Berkowitz SA. Medical-Imaging Stewardship in the Accountable Care Era. The New England journal of medicine 2015;373:1691-3.
15. Mazziotti S, Cicero G, D'Angelo T, et al. Imaging and Management of Incidental Renal Lesions. BioMed research international 2017;2017:1854027.
16. Lumbreras B, Donat L, Hernández-Aguado I. Incidental findings in imaging diagnostic tests: a systematic review. The British journal of radiology 2010;83:276-89.
17. Bunnik EM, van Bodegom L, Pinxten W, de Beaufort ID, Vernooij MW. Ethical framework for the detection, management and communication of incidental findings in imaging studies, building on an interview study of researchers' practices and perspectives. BMC medical ethics 2017;18:10.
18. Niesen TJ, Finch N, Gakhal M, Dressler RM, Levy HM. Value of prior imaging review before ordering renal sonography in the evaluation of abnormal renal function. Journal of clinical ultrasound : JCU 2017;45:537-41.

Tables

Table 1. Baseline characteristics of patients by risk group for hydronephrosis.

	High-risk (%, n = 111)	Medium-risk (%, n = 76)	Low-risk (%, n = 94)	p-value
Sociodemographics				
Age				
18-39	9%	7%	12%	0.30
40-59	19%	22%	31%	
60-74	37%	42%	33%	
≥75	35%	29%	24%	
Sex				
Male	64%	51%	53%	0.15
Female	36%	49%	47%	
Race/Ethnicity				
Non-Hispanic White	34%	24%	11%	<0.001*
Non-Hispanic Black	14%	39%	63%	
Hispanic	32%	29%	22%	
Other	20%	8%	4%	
Risk Criteria				
History of hydronephrosis	27%	0%	0%	<0.001*
Nonblack race	86%	61%	37%	<0.001*
History of recurrent UTIs	18%	3%	1%	<0.001*
Diagnosis c/w possible obstruction	70%	45%	16%	<0.001*
Absence of nephrotoxins	68%	39%	10%	<0.001*
Absence of CHF	92%	86%	44%	<0.001*
Absence of prerenal AKI	78%	67%	53%	0.005*
Laboratory Results				
Creatinine at admission, mean (SD)	4.2 (4.1)	3.7 (3.9)	3.0 (2.3)	0.048*
Baseline Creatinine, mean (SD)	2 (1.5)	1.8 (1.3)	1.6 (0.9)	0.078

* Statistically significant at $p < 0.05$.
UTIs – urinary tract infections; CHF – congestive heart failure; AKI – acute kidney injury; SD – standard deviation.

Table 2. Baseline characteristics of patients by nephrology consultation.

	Nephrology Consult, RUS Recommended (%, n = 95)	Nephrology Consult, RUS Not Recommended (%, n = 73)	No Nephrology Consult (%, n = 113)	p-value
Sociodemographics				
Age				
18-39	12%	7%	9%	0.70
40-59	23%	26%	23%	
60-74	41%	37%	34%	
≥75	24%	30%	35%	
Sex				
Male	56%	56%	58%	0.92
Female	44%	44%	42%	
Race/Ethnicity				
Non-Hispanic White	28%	22%	20%	0.30
Non-Hispanic Black	31%	36%	44%	
Hispanic	28%	34%	23%	
Other	13%	8%	12%	
Risk Criteria				
History of hydronephrosis	9%	10%	12%	0.75
Nonblack race	69%	64%	56%	0.12
History of recurrent UTIs	1%	4%	17%	<0.001*
Diagnosis c/w possible obstruction	40%	45%	50%	0.39
Absence of nephrotoxins	39%	37%	44%	0.57
Absence of CHF	67%	77%	78%	0.19
Absence of prerenal AKI	68%	60%	66%	0.53
Laboratory Results				
Creatinine at admission, mean (SD)	5.2 (4.4)	4.0 (3.6)	2.2 (1.6)	<0.001*
Baseline Creatinine, mean (SD)	2.3 (1.4)	2.0 (1.4)	1.3 (0.7)	<0.001*

* Statistically significant at $p < 0.05$.
RUS – renal ultrasound; UTIs – urinary tract infections; CHF – congestive heart failure; AKI – acute kidney injury; SD – standard deviation.

Table 3: Risk stratification versus nephrology consult recommendation for RUS in hospitalized patients with AKI and prevalence of hydronephrosis.

	Total cases (N = 281)	Hydronephrosis (N = 35)	Hydronephrosis (%)
Risk Stratification			
High-risk	111	30	27%
Medium-risk	76	1	1%
Low-risk	94	4	4%
Nephrology Consult Recommendation			
RUS Recommended	95	9	9%
Not Recommended	73	7	10%
No Nephrology Consult	113	19	17%

RUS – renal ultrasound; AKI – acute kidney injury.

Table 4: Reason for RUS exam.

Reason for Exam	Total (N = 236)* Number (%)
AKI or renal failure	134 (57)
Rule out hydronephrosis or obstruction	56 (24)
Oliguria or anuria	9 (4)
Rule out pyelonephritis or abscess	6 (3)
Other	6 (3)
Evaluate for nephrolithiasis	4 (2)
ESRD or new ESRD	4 (2)
CKD	4 (2)
Recurrent UTIs	3 (1)
Costovertebral tenderness or flank pain	3 (1)
Evaluate ureteral stent or nephrostomy tube	2 (1)
Hematuria	2 (1)
Concern for hepatorenal syndrome	2 (1)
Renal cyst or mass seen on CT scan	1 (0.4)
Obstructive nephrolithiasis	1 (0.4)

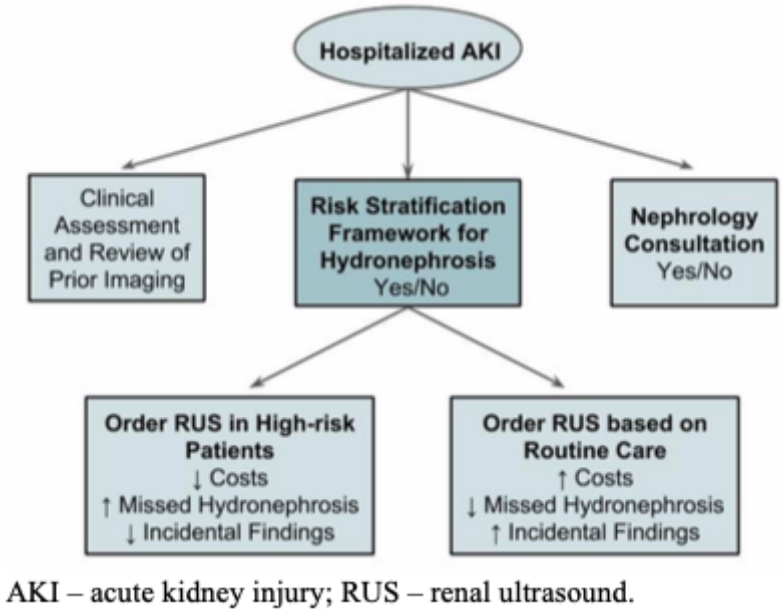
*Excludes exams with “Reason for exam” listed as blank or N/A.
RUS – Renal ultrasound; AKI – acute kidney injury; ESRD – end-stage renal disease; CKD – chronic kidney disease; UTIs – urinary tract infections; CT – computed tomography.

Table 5: Ultrasound findings by risk group.

Finding	High-risk (%, n = 111)	Medium-risk (%, n = 76)	Low-risk (%, n = 94)	p-value
Increased renal parenchymal echogenicity	65%	72%	72%	0.41
Simple cyst	39%	33%	35%	0.70
Other	25%	20%	27%	0.55
Complex cyst	14%	12%	11%	0.82
Bilateral hydronephrosis	14%	1%	1%	<0.001*
Unilateral hydronephrosis	13%	0%	3%	0.001*
Renal atrophy or cortical thinning	11%	13%	7%	0.47
No abnormalities	10%	15%	16%	0.41
Non-obstructive nephrolithiasis	8%	5%	9%	0.69
Renal mass	4%	3%	2%	0.81
Renal enlargement	4%	3%	2%	0.81
Absence of kidney (whole or partial, congenital or acquired)	4%	1%	3%	0.63
Obstructive nephrolithiasis	2%	1%	0%	0.44

* Statistically significant at $p < 0.05$.
There were no patients with staghorn calculi, anatomic urinary tract abnormalities, mass of genitourinary tract, other abdominal mass, pelvic kidney, or horseshoe kidney.

Figures



AKI – acute kidney injury; RUS – renal ultrasound.

Figure 1

Framework for ordering RUS in hospitalized patients with AKI.

Supplementary Files

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- supplement1.doc