Routine screening for hepatitis C viral infection in patients undergoing elective cranial neurosurgery

Eric S. Nussbaum, MD,¹ Kevin Kallmes, MA,² Jodi Lowary, CNP,¹ and Leslie A. Nussbaum, MD, PhD³

¹National Brain Aneurysm Center, Department of Neurosurgery, United Hospital, St. Paul, Minnesota; ²Duke University Law School, Durham, North Carolina; and ³Minnesota Neurovascular & Skull Base Surgery, Minneapolis, Minnesota

OBJECTIVE Undiagnosed hepatitis C virus (HCV) and HIV in patients present risks of transmission of bloodborne infections to surgeons intraoperatively. Presurgical screening has been suggested as a protocol to protect surgical staff from these pathogens. The authors sought to determine the incidence of HCV and HIV infection in elective craniotomy patients and analyze the cost-effectiveness of universal and risk factor–specific screening for protection of the surgical staff.

METHODS All patients undergoing elective craniotomy between July 2009 and July 2016 at the National Brain Aneurysm Center who did not refuse screening were included in this study. The authors utilized rapid HCV and HIV tests to screen patients prior to elective surgery, and for each patient who tested positive using the rapid HCV or HIV test, qualitative nucleic acid testing was used to confirm active viral load, and risk factor information was collected. Patients scheduled for nonurgent surgery who were found to be HCV positive were referred to a hepatologist for preoperative treatment. The authors compared risk factors between patients who tested positive on rapid tests, patients with active viral loads, and a random sample of patients who tested negative. The authors also tracked the clinical and material costs of HCV and HIV rapid test screening per patient for cost-effectiveness analysis and calculated the cost per positive result of screening all patients and of screening based on all patient risk factors that differed significantly between patients with and those without positive HCV test results.

RESULTS The study population of patients scheduled for elective craniotomy included 1461 patients, of whom 22 (1.5%) refused the screening. Of the 1439 patients screened, 15 (1.0%) tested positive for HCV using rapid HCV screening; 9 (60%) of these patients had active viral loads. No patient (0%) tested positive for HIV. Seven (77.8%) of the 9 patients with active viral loads underwent treatment with a hepatologist and were referred back for surgery 3–6 months after sustained virologic response to treatment, but the remaining 2 patients (22.2%) required urgent surgery. Of the 9 patients with active viral loads, 1 patient (11%) had a history of both intravenous drug abuse and tattoos. Two of the 9 patients (22%) had tattoos, and 3 (33%) were born within the age-screening bracket (born 1945–1965) recommended by the Centers for Disease Control and Prevention. Rates of smoking differed significantly ($p < 0.001$) between patients who had active viral loads of HCV and patients who were HCV negative, and rates of smoking ($p < 0.001$) and IV drug abuse ($p < 0.01$) differed significantly between patients who were HCV rapid-test positive and those who were HCV negative. Total screening costs (95% CI) per positive result were \$3,877.33 (\$2,348.05–\$11,119.28) for all patients undergoing HCV rapid screening, \$226.29 (\$93.54–\$312.68) for patients with a history of smoking, and \$72.00 (\$29.15–\$619.39) for patients with a history of IV drug abuse.

CONCLUSIONS The rate of undiagnosed HCV infection in this patient population was commensurate with national levels. While the cost of universal screening was considerable, screening patients based on a history of smoking or IV drug abuse would likely reduce costs per positive result greatly and potentially provide cost-effective identification and treatment of HCV patients and surgical staff protection. HIV screening found no infected patients and was not cost-effective.

<https://thejns.org/doi/abs/10.3171/2018.4.JNS172475>

KEYWORDS hepatitis C virus; human immunodeficiency virus; elective craniotomy; universal screening; infection

ABBREVIATIONS CDC = Centers for Disease Control and Prevention; HBV = hepatitis B virus; HCV = hepatitis C virus; IV = intravenous; SVR = sustained virologic response.

SUBMITTED October 2, 2017. **ACCEPTED** April 5, 2018.

INCLUDE WHEN CITING Published online September 14, 2018; DOI: 10.3171/2018.4.JNS172475.

As of 2010, 3.4–4.9 million people in the United States were infected with the hepatitis C virus (HCV), making up roughly 1% of the population,^{6,15} and the Centers for Disease Control and Prevention (CDC) has estimated that over 30,500 new infections occur annually.²¹ Transmission rates following blood-to-blood contact or other subcutaneous contamination with infected biological material are difficult to measure and are estimated at 2%–10%.²⁶ Though over 80% of patients treated for HCV now show a sustained virologic response (SVR) to treatment at 12–24 weeks,¹⁶ HCV remains a leading cause of chronic liver disease, largely because an estimated 50% of infections are undiagnosed.¹

Operating on HCV-positive patients presents substantial risk to surgeons, particularly orthopedic and hepatic surgeons, as orthopedic surgeons face an especially high risk of puncture and exposure to aerosolized bone and hepatic surgeons are more likely to operate on infected individuals.⁹ Based on these risks and the large estimated population of undiagnosed HCV-positive patients, universal screening has been suggested for HCV in patients undergoing orthopedic surgery⁵ and has been undertaken in multiple surgical disciplines in high-risk regions.^{2,13,22} This screening is in addition to general screening of patients based on known risk factors, such as intravenous (IV) drug abuse and unlicensed tattoos, as well as the CDC-recommended one-time screening of all individuals born between 1945 and 1965.⁷ Such screening practices also allow the initiation of timely treatment to avoid adverse effects on the patient through liver-related complications and can affect anesthetic management.⁴

According to the CDC, HIV has a prevalence of roughly 1.1 million in the United States (0.3%) and infects 56,300 people per year.¹⁹ However, the risk of intraoperative procedure-related transmission of HIV, at 0.3%, is much lower than that of HCV, estimated to be about 2%.⁹ The lower transmission rate and prevalence make screening for HIV less cost-effective than for HCV, but the serious lifelong consequences of HIV infection³ have led to considerations of screening all patients before orthopedic²⁷ and neurosurgical procedures.¹⁰

Based on the risks of intraoperative communication of bloodborne HCV and HIV to surgeons, the National Brain Aneurysm Center enacted a policy of prescreening all elective craniotomy patients for HCV and HIV beginning in July 2009. The purpose of this study was to determine the incidence of HCV and HIV in these patients and analyze the risk factors for these infections, the cost-effectiveness of screening, and the potential for future screening in neurosurgical clinics.

Methods

Design and execution of this single-center retrospective study was subject to Health Insurance Portability and Accountability Act guidelines on patient data integrity and privacy. Institutional IRB approval was obtained, and informed consent for screening was given by all patients who were included in the study.

Study Population

All patients undergoing elective craniotomy between July 2009 and July 2016 at the National Brain Aneurysm Center were considered eligible for our cross-sectional study. As part of an institutional policy to protect health-care workers, these patients were screened preoperatively for both HCV and HIV using rapid tests, and testing was billed as part of presurgical care. Exclusion criteria for our study included patient refusal of screening for one or both viruses and failure of the primary physician to enroll the patient and collect serum samples due to technical difficulties or oversight.

Hepatitis C Screening

For HCV rapid screening, we utilized the quantitative Abbott Anti-HCV Chemiluminescent Microparticle Immunoassay (Abbott Laboratories). Each patient whose test result was above the manufacturer-recommended viral load threshold of $\geq 10^3$ IU/ml using the rapid HCV test was flagged based on previously reported practices,^{8,23} and the primary physician collected background characteristics and risk factors, including history of IV drug abuse, smoking, alcoholism, sexual activity, diabetes, dialysis, hypertension, cirrhosis, and other relevant comorbidities. These flagged patients then underwent more detailed testing using a qualitative nucleic acid HCV test to differentiate patients with an active viral load or a cleared infection. Any patients who were found to have an active viral load on further testing were referred to a hepatologist for treatment. The remaining patients were considered to have been infected with HCV but spontaneously cleared of the infection. Hepatitis B virus (HBV) testing was not performed, as all healthcare providers are immunized against this disease, per institution policy, meaning that such screening was unnecessary to protect surgical staff.

HCV Patient Care

Patients with active HCV loads had their elective craniotomies postponed and were referred to a hepatologist for treatment. For patients whose surgeries were not urgent, we performed the procedure 3–6 months after the patient achieved SVR. For patients whose neurological symptoms were worsening during treatment for HCV to the point that urgent surgery was required, we performed the procedure with careful attention to surgical best practices with HCV-positive patients.⁴ We used a single operating room scrub nurse, avoided having trainees in the operating room, removed all tools from the operating table after their use was completed, and given that the most common intraoperative injury is needle puncture of the nondominant hand during suturing,²⁴ avoided distractions such as counting surgical items during closure.

HIV Screening

For HIV screening, we utilized the OraQuick Advance HIV-1/2 rapid antibody test (OraSure Technologies) using venipuncture whole blood from each subject. Blood was obtained by the primary physician's nursing staff. For each patient who tested positive using the rapid OraQuick

HIV test, the primary physician collected data regarding background characteristics and risk factors, including history of IV drug use, smoking, alcoholism, sexual activity, diabetes, hypertension, cirrhosis, and other relevant comorbidities.

Statistical Analysis

To determine the risk factors that were significantly associated with HCV, we compared rates of hypertension, smoking, diabetes, dialysis, and IV drug abuse between patients with an active HCV viral load and a random sample of HCV-negative patients, as well as between patients who tested positive for HCV on the rapid test and the random sample of HCV-negative patients. We used Fisher's exact test for this comparison, and $p < 0.05$ was considered significant for all tests. The equal-tailed Jeffreys interval method was used to calculate 95% CIs for each risk factor in both groups and 95% CIs for proportions of HCV-positive patients drawn from total subpopulations of patients screened for IV drug abuse or smoking. Based on the prevalence and CIs obtained for patient risk factors, the cost per positive HCV result and 95% CIs thereof were estimated using the following formula: (cost of test, \$) $\times$ (total subpopulation)/(HCV-positive patients), with correction for multiple comparisons (HCV-positive and HCV-negative populations included in the same cost calculation). All statistical analyses were performed in RStudio (version 1.0.153).

Cost-Effectiveness Calculation

For cost-effectiveness analysis, we kept track of the clinical and material costs of our HCV and HIV rapid test screening per patient. We calculated the cost of identifying patients with an active or cleared viral load by multiplying the cost of rapid test materials by the number of patients and dividing by the number of positive patients. This established our costs of universal rapid screening relative to the benefit in diagnostic information, which could then be compared to the estimated cost of allowing HCV or HIV to pass undiagnosed. For each statistically significant risk factor, we completed a cost-effectiveness analysis for selectively screening patients with that risk factor. We also calculated the 95% CIs for these risk factor groups.

Results

We included 1461 patients during the study period. Twenty-two patients (1.5%) requested that the primary physician not perform the screening as part of the pre-operative workup, and these patients were excluded from this study. No patients were excluded because of technical difficulties or oversight. The average patient age was 54 years (range 19–96 years), and 62% of patients were female (892/1439). Race, insurance status, and the most common surgeries completed are summarized in Table 1. There were no false positives for either HIV or HCV tests.

HCV Results

Of the 1439 patients screened, 15 (1.0%) tested posi-

TABLE 1. Background characteristics of all screened patients

Clinical Characteristics	Patients (N = 1439)
Age in yrs, mean (range)	54 (19–96)
Sex, n (%)	
Male	547 (38%)
Female	892 (62%)
Race, n (%)	
Caucasian	1266 (88%)
African American	72 (5.0%)
Asian	43 (3.0%)
Hispanic	30 (2.1%)
Other	28 (1.9%)
Insurance, n (%)	
Private	899 (62.5%)
Medicare/Medicaid	530 (36.8%)
None	10 (0.7%)

The most common surgeries were 1) aneurysm clipping, wrapping, or bypass; 2) brain tumor resection; 3) arteriovenous malformation; 4) cerebrovascular insufficiency; and 5) subdural hematoma.

tive for HCV using rapid HCV screening. Of these 15 patients, 6 (40%) were found to have no active viral load when tested using a qualitative HCV nucleic acid test, indicating that they had spontaneously cleared the infection at some point in the past. Nine patients (60%) had active viral loads, meaning that 0.6% of our total patient population had active HCV infections. Risk factor comparisons between 250 randomly sampled HCV-negative patients and patients who tested positive using the HCV rapid test and patients with an active HCV viral load are shown in shown Tables 2 and 3, respectively.

Characteristics and Treatment of HCV-Positive Patients

The patients who initially tested positive for HCV using the rapid test had an average age of 46 years (range 25–62 years) and included 12 women and 3 men. Eleven patients (73%) had a history of cigarette smoking, 6 (40%) had a history of hypertension, and 2 (13%) had been diagnosed with diabetes. The risk factors that were present in this group included tattoos as the only known risk exposure in 4 patients (27%), history of IV drug abuse in 2 patients (13%), and previous diagnosis of HCV that was not treated, admitted in retrospect by 1 patient (6.7%) (Table 2). No HCV-positive patients were on dialysis. Three patients (20%) denied having any known risk factors. HCV-positive risk factors are presented on a per-patient basis in Table 4.

Of the 9 patients with active viral loads, 1 patient (11%) had history of both IV drug abuse and tattoos. Two further patients (22%) had tattoos, and 3 of the 9 patients (33%) were born within the CDC-recommended age-screening bracket (1945–1965). Seven patients with active viral loads (78%) underwent treatment with a hepatologist and were referred back for surgery 3–6 months after SVR. However, 2 patients (22%) required urgent surgery before HCV treatment due to deteriorating neurological condition; one

TABLE 2. Risk factor comparison between patients with HCV-positive and HCV-negative rapid test results

Risk Factor	HCV Positive (n = 15)	Fraction* (95% CI)	HCV Negative (n = 250)†	Fraction* (95% CI)	p Value‡	Cost per Positive Result (95% CI)§
Hypertension	6 (40%)	0.40 (0.152–0.648)	60 (24%)	0.24 (0.187–0.293)	0.215	
Smoking	11 (73%)	0.733 (0.509–0.957)	55 (22%)	0.22 (0.169–0.271)	0.0001	\$144.00 (\$93.54–\$312.68)
Diabetes	2 (13%)	0.133 (–0.039 to 0.305)	28 (11%)	0.112 (0.073–0.151)	0.681	
Dialysis	0 (0%)	0 (–0.118 to 0.118)	1 (0.4%)	0.004 (–0.004 to 0.012)	0.999	
IV drug abuse	2 (13%)	0.133 (–0.039 to 0.305)	1 (0.4%)	0.004 (–0.004 to 0.012)	0.0087	\$36.00 (\$24.97–\$135.80)

Values are number of patients (%) unless otherwise indicated.

* Fraction of patients in the HCV-positive or HCV-negative group with each respective risk factor. Statistical tests compare fractions of patients with each risk factor.

† 250 patients were randomly selected from the 1424 HCV-negative patients to compare to the HCV-positive patients concerning risk factors.

‡ Fisher exact test statistic value based on comparison of the rates of risk factors between HCV-positive and HCV-negative patients.

§ Cost per positive result calculated as (cost of test, \$) × (total subpopulation)/(HCV-positive patients); this was completed only for comparisons that were statistically significant between patients with HCV-positive rapid test results and HCV-negative patients.

had an expanding subdural hematoma and the other had a complex aneurysm with worsening headaches. For these patients, we performed surgery using the protocol outlined above. Comparison of prevalence between patients with active viral loads and HCV-negative patients is presented in Table 3.

Characteristics of a Sample of HCV-Negative Patients

In a random sample of 250 patients who were HCV negative, we found that 60 patients had hypertension (24%), 55 had a history of smoking (22%), 28 had been diagnosed with diabetes (11%), and 1 patient (0.4%) was on dialysis. One patient had a history of IV drug abuse (0.4%), but no data were recorded concerning tattoos for patients who were negative for HCV (Table 2).

Risk Factor Comparison Between HCV-Positive and HCV-Negative Patients

When comparing rates of hypertension, smoking, diabetes, dialysis, and IV drug abuse rates between patients with active viral loads and patients who were HCV negative, we found that patients with active viral loads were significantly more likely to have a history of smoking (p

< 0.001). No other risk factor had a significant association between active viral load (hypertension, $p = 0.231$; diabetes, $p = 0.280$; dialysis, $p = 0.99$; see Table 3 and Fig. 1); the risk factor of IV drug abuse produced a p value of 0.068. When the same comparisons were made between patients who tested positive on HCV rapid tests, we found that these patients were significantly more likely to have a history of smoking ($p < 0.001$) and be past IV drug abusers ($p < 0.01$) (see Table 2 and Fig. 1).

HIV Results

Of the 1454 patients screened, none (0.0%) tested positive for HIV using the OraQuick rapid test. Therefore, there were no relevant background characteristics concerning risk factors for HIV in our patient population.

Cost per Positive Result

The total cost of the HCV and HIV screening was \$74,154. Our cost per patient for the HCV rapid screening test was \$24, which was slightly higher than the average observed in past cost calculations for HCV (total cost: \$34,896).¹¹ Therefore, since 9 patients were identified to have an active HCV load, and 1454 patients were screened

TABLE 3. Risk factor comparison between patients with an active HCV viral load and HCV-negative patients

Risk Factor	Active HCV Viral Load (n = 9)	Fraction* (95% CI)	HCV Negative (n = 250)†	Fraction* (95% CI)	p Value‡	Cost per Positive Result (95% CI)§
Hypertension	4 (44%)	0.444 (0.119–0.769)	60 (24%)	0.24 (0.187–0.293)	0.238	
Smoking	7 (78%)	0.777 (0.505–1.409)	55 (22%)	0.22 (0.169–0.271)	0.0008	\$226.29 (\$133.08–\$755.32)
Diabetes	2 (22%)	0.222 (–0.05 to 0.494)	28 (11%)	0.112 (0.073–0.151)	0.280	
Dialysis	0 (0%)	0 (–0.187 to 0.187)	1 (0.4%)	0.004 (–0.004 to 0.012)	0.999	
IV drug abuse	1 (11%)	0.111 (–0.094 to 0.316)	1 (0.4%)	0.004 (–0.004 to 0.012)	0.068	\$72.00 (\$29.15–\$619.39)

Values are number of patients (%) unless otherwise indicated.

* Fraction of patients in the HCV-positive or HCV-negative group with each respective risk factor. Statistical tests compare fractions of patients with each risk factor.

† 250 patients were randomly selected from the 1424 HCV-negative patients to compare to the HCV-positive patients concerning risk factors.

‡ Fisher exact test statistic value based on comparison of the rates of risk factors between HCV-positive and HCV-negative patients.

§ Cost per positive result calculated as (cost of test, \$) × (total subpopulation)/(HCV-positive patients); completed only for the statistically significant comparison between patients with an active HCV viral load and HCV-negative patients with a history of smoking and the comparison between the patient groups with a history of IV drug abuse, which was significant for rapid test result group comparisons (see Table 2).

TABLE 4. Characteristics of patients with positive results for rapid HCV screening

Pt No.	Active Viral Load	HCV Risk Factors						
		Age (yrs)	Hypertension	Smoking	Diabetes	Dialysis	IV Drug Abuse	Tattoos
1	+	25		✓				✓
2	-	31						
3	-	38		✓			✓	✓
4	+	42		✓				✓
5	+	45	✓	✓			✓	✓
6	+	46						
7	-	47		✓				
8	+	49		✓				
9	-	50	✓	✓				
10	+	52	✓	✓				
11	+	56						
12	+	58	✓	✓	✓			
13	-	61		✓				
14	+	62	✓	✓	✓			
15	-	62	✓					

Pt = patient.

HCV screening was completed with an Abbott Anti-HCV chemiluminescent microparticle immunoassay. Patients were then tested with a qualitative nucleic acid HCV test to differentiate patients with an active viral load. Patients 11–15 fall within the birth cohort for CDC-recommended one-time HCV screening (born 1945–1965).

in total, our cost per positive result was $(\$24 \times 1454 \text{ patients screened})/9 \text{ positive results} = \$3,877.33$ (95% CI \$2,348.05–\$11,119.28).

Concerning statistically significant risk factors, when we compared patients with active viral infections to our random sample of HCV-negative patients, we found that 7 of 62 smokers (11%) were HCV positive; this means that

our total cost per positive result among smokers was $(\$24 \times 62 \text{ smokers screened})/7 \text{ positive results} = \226.29 (95% CI \$93.54–\$312.68). We found that 1 of 2 IV drug abusers (50%) were HCV positive, meaning that our cost per positive result among IV drug abusers was $(\$24 \times 2 \text{ IV drug abusers screened})/1 \text{ positive results} = \72.00 (95% CI \$29.15–\$619.39).

FIG. 1. Histogram of patient characteristics between patients who tested positive for HCV (Hep+) on the initial rapid test ($n = 15$), Hep+ patients who had an active viral load on a subsequent qualitative HCV test ($n = 9$), and patients who were HCV-negative (Hep-) ($n = 250$). Error bars represent 95% CIs; differences in risk factors between groups were statistically significant ($p < 0.05$) for the following: history of smoking, between Hep+ (active viral load) and Hep-; history of smoking or IV drug abuse, between Hep+ (on rapid test) and Hep-.

If all patients who had ever contracted HCV were included, our costs per positive result were \$2,326.40 (95% CI \$1,547.38–\$4,685.07) for all patients, \$144.00 (95% CI \$93.54–\$312.68) for patients with a history of smoking, and \$36.00 (95% CI \$24.97–\$135.80) for IV drug abusers.

Our cost per patient for HIV rapid screening was \$27. Therefore, since none of our patients were identified to have an active viral load, we spent a total of \$39,258 on HIV screening without identifying a single HIV-positive patient, representing an indeterminate cost per positive result.

Discussion

Screening Results

Our screening of patients for HCV and HIV before elective craniotomy found a rate of active HCV infection that roughly correlated to the estimated prevalence of undiagnosed HCV in the US general population. The patients who either tested positive for an active viral load of HCV or had an indication of clearing it spontaneously in the past had high rates of smoking, hypertension, and exposure through tattoos or IV drug use; however, of these risk factors, only smoking and IV drug use were significantly higher than in HCV-negative patients.

Since the late 1990s, the CDC has recommended testing for individuals considered “high risk” for HCV, and in 2012 the CDC expanded their recommendation to include individuals born between 1945 and 1965.⁷ Based on birth cohort-specific screening, we would expect that one third of our patients should have been screened based on this recommendation.

Gańczak and Szych have reported the only previous study of universal preoperative screening for HCV or HIV in a neurosurgical department, in which 100 patients at a Polish hospital were consecutively screened; 4 patients (4.0%) tested positive for either HCV or HBV and none tested positive for HIV.¹⁰ Preoperative HCV and HIV screening was completed in over 10,000 patients in one orthopedic clinic, of whom only 4 (0.04%) were HCV positive and none were HIV positive, leading to a suggestion that universal preoperative screening was not worth the cost and effort.²⁷ An Italian orthopedics and traumatology ward disagreed and recommended that universal HCV screening was necessary based on the 4% infection rate among their patients.²⁵ An emergency department in Baltimore found that 18% of 2500 patients from whom blood was drawn were HCV positive and 6% were HIV positive,¹⁴ while 11% of 650 cataract surgery patients in a Pakistani clinic were HCV positive.²² Lastly, an Italian clinic reported 4% HCV-positive and 11% HIV-positive rates in patients undergoing gender reassignment surgery. These wide-ranging rates of undiagnosed HCV are likely due to regional and risk factor-specific variation.

Cost-Effectiveness

HCV rapid test screening cost roughly \$3900 per positive result but contributed not only to improved prognoses for our patients but the removal of health risk from our surgical staff. However, since no patients tested positive for HIV, the cost for screening came with no health benefit for our patients or surgical staff.

Costs per positive result for HCV testing of smokers (\$144) and IV drug abusers (\$36) were far lower than those for patients without these risk factors; this finding represents strong evidence that HCV screening of patients with a history of smoking or IV drug abuse is a cost-effective measure for both protecting hospital staff and discovering and treating HCV. Hospitals may want to screen universally as a protective measure for surgical staff, but risk factor-based screening is far more cost-effective and almost certainly would represent a lower social cost in terms of both health outcomes and total medical costs than eventual treatment given the prevalence of HCV,⁶ its high transmission rates,²⁶ and surgical reports that almost 7% of operations involve percutaneous injuries to the surgeon.²⁴ Even if the patient population in question does not have undiagnosed HCV at a rate higher than the general population of the United States (as is true of our screening report), this screening is likely to be cost-effective.

A high rate of IV drug abusers were HCV positive, and screening patients with a history of drug abuse is likely a cost-effective strategy of HCV detection and surgical staff protection.¹¹ However, a larger sample size is necessary to corroborate this finding, as our risk factor comparisons for IV drug abuse were significant only for patients with positive rapid-test results, not patients with an active viral load. The potentially lower cost-effectiveness of selectively screening patients with a history of smoking than IV drug abusers could be due to the larger sample population, as roughly 15% of the US population actively smokes cigarettes.¹² However, selective screening based on a history of smoking still lowers the cost per positive result by roughly 86%–92% compared to universal screening. Our findings concerning smoking are especially notable, as a history of smoking (unlike IV drug abuse) is not an indicator that a patient should be screened according to the CDC.⁷

Aforementioned evidence from studies in the setting of orthopedic surgery²⁷ and analyses of cost-effectiveness¹¹ corroborate our findings that the cost-effectiveness of screening differed greatly based on risk factors: a cost per positive result of \$54 was found for IV drug abusers, and men who had had > 100 sexual partners had a cost per positive result of \$155, while men and women who were not IV drug abusers and who had had < 100 sexual partners had a cost per positive result of \$1,386 and \$2,986, respectively. Based on these findings and the risk factors of HCV-positive patients in our study, targeted screening of patients reporting a history of IV drug abuse, smoking, or > 100 sexual partners can be an extremely cost-effective method by which neurosurgical and other clinics can protect their staff and contribute to public health.

Our screening for HIV resulted in no new diagnoses, from which we conclude that universal HIV screening for neurosurgical patients regardless of risk factors is likely not cost-effective in a clinic with our patient characteristics. Our results may not be generalizable to practices with higher-risk patient populations, such as emergency departments in high-risk regions.¹⁴ This is supported by the lack of HIV-positive patients reported from the orthopedic or ophthalmic clinics above. Studies of groups at high risk for HIV, such as patients undergoing male-to-female sex reassignment surgery,¹⁸ immigrants from countries with large HIV-positive

populations,¹⁷ IV drug abusers, and gay or bisexual men,²⁰ suggest that HIV screening of high-risk groups is crucial to public health, so a more targeted approach in neurosurgical patients based on patient history may be warranted.

Limitations

Our report has several limitations. The lack of reported infection rates of HCV among surgical staff limits our ability to determine whether screening strategies are cost-effective in protecting surgical staff. Our study had a very small number of patients with a history of IV drug abuse, and the high rate of HCV found in these patients may therefore not be representative of the population at large; however, corroboration from other cost-effectiveness studies strengthens our conclusions. We also were unable to present the percentage of HCV-negative patients with tattoos, precluding cost-effectiveness analysis for this risk factor. We based our HCV-negative background characteristics on a random sample of 250 patients, which presents lower statistical power than using our whole study population. We did not screen for HBV, and we did not include the costs of subsequent testing in our cost-effectiveness calculation for HCV screening. Lastly, we did not collect information on history of sexual activity or immigration status, which may also be relevant risk factors.

Conclusions

Our universal preoperative screening for HCV and HIV in elective craniotomy patients found a rate of undiagnosed HCV infection commensurate with national levels at a screening cost that is far exceeded by expected treatment costs of allowing the risk of ongoing infection. While this HCV screening strategy aided patient treatment and reduced the risk of infection to surgical staff, our HIV screening revealed no cases of HIV infection and thus provided no additional diagnostic information.

Acknowledgments

We acknowledge the research and drafting support of Superior Medical Experts. We would also like to acknowledge the nursing staff of the National Brain Aneurysm Center for their dedicated assistance with each of these patients. We received a grant from the United Hospital Foundation in support of this work.

References

1. AASLD/IDSA HCV Guidance Panel: Hepatitis C guidance: AASLD-IDSA recommendations for testing, managing, and treating adults infected with hepatitis C virus. **Hepatology** **62**:932–954, 2015
2. Ahmed R, Bhattacharya S: Universal screening versus universal precautions in the context of preoperative screening for HIV, HBV, HCV in India. **Indian J Med Microbiol** **31**:219–225, 2013
3. Arts EJ, Hazuda DJ: HIV-1 antiretroviral drug therapy. **Cold Spring Harb Perspect Med** **2**:a007161, 2012
4. Asthana S, Kneteman N: Operating on a patient with hepatitis C. **Can J Surg** **52**:337–342, 2009
5. DelSole EM, Mercuri JJ, Stachel A, Phillips MS, Zuckerman JD: Risk of hepatitis C virus exposure in orthopedic surgery: is universal screening needed? **Am J Orthop** **43**:E117–E123, 2014
6. Denniston MM, Jiles RB, Drobeniuc J, Kleven RM, Ward JW, McQuillan GM, et al: Chronic hepatitis C virus infection in the United States, National Health and Nutrition Examination Survey 2003 to 2010. **Ann Intern Med** **160**:293–300, 2014
7. Division of Viral Hepatitis: **Viral Hepatitis: Testing Recommendations**. Atlanta, GA: Centers for Disease Control & Prevention, 2015
8. Ergünay K, Şener B, Alp A, Karakaya J, Haşcelik G: Utility of a commercial quantitative hepatitis C virus core antigen assay in a diagnostic laboratory setting. **Diagn Microbiol Infect Dis** **70**:486–491, 2011
9. Fisher WD: Hepatitis C and the surgeon. **Can J Surg** **56**:80–81, 2013
10. Gańczak M, Szych Z: Infections with HBV, HCV and HIV in patients admitted to the neurosurgical department of a teaching hospital. **Neurol Neurochir Pol** **42**:231–237, 2008
11. Honeycutt AA, Harris JL, Khavjou O, Buffington J, Jones TS, Rein DB: The costs and impacts of testing for hepatitis C virus antibody in public STD clinics. **Public Health Rep** **122** (Suppl 2):55–62, 2007
12. Jamal A, King BA, Neff LJ, Whitmill J, Babb SD, Graffunder CM: Current cigarette smoking among adults—United States, 2005–2015. **MMWR Morb Mortal Wkly Rep** **65**:1205–1211, 2016
13. Jun Z, Zhen C, QuiuLi Z, YuanQi A, Casado VV, Fan Y: Screening for human immunodeficiency virus, hepatitis B virus, hepatitis C Virus, and Treponema pallidum by blood testing using a Bio-Flash technology-based algorithm before gastrointestinal endoscopy. **J Clin Microbiol** **54**:3000–3006, 2016
14. Kelen GD, Green GB, Purcell RH, Chan DW, Qaqish BF, Sivertson KT, et al: Hepatitis B and hepatitis C in emergency department patients. **N Engl J Med** **326**:1399–1404, 1992
15. Kim AY, Onofrey S, Church DR: An epidemiologic update on hepatitis C infection in persons living with or at risk of HIV infection. **J Infect Dis** **207** (Suppl 1):S1–S6, 2013
16. Kohli A, Shaffer A, Sherman A, Kottlil S: Treatment of hepatitis C: a systematic review. **JAMA** **312**:631–640, 2014
17. Liddicoat RV, Horton NJ, Urban R, Maier E, Christiansen D, Samet JH: Assessing missed opportunities for HIV testing in medical settings. **J Gen Intern Med** **19**:349–356, 2004
18. Luzzati R, Zatta M, Pavan N, Serafin M, Maurel C, Trombetta C, et al: Prevalence of human immunodeficiency virus, hepatitis B virus, and hepatitis C virus infections among transgender persons referred to an Italian center for total sex reassignment surgery. **Sex Transm Dis** **43**:407–411, 2016
19. Moore RD: Epidemiology of HIV infection in the United States: implications for linkage to care. **Clin Infect Dis** **52** (2 Suppl 2):S208–S213, 2011
20. Rizza SA, MacGowan RJ, Purcell DW, Branson BM, Temesgen Z: HIV screening in the health care setting: status, barriers, and potential solutions. **Mayo Clin Proc** **87**:915–924, 2012
21. Spach DH: HCV epidemiology in the United States. **Hepatitis C Online**. (<https://www.hepatitisc.uw.edu/go/screening-diagnosis/epidemiology-us/core-concept/all>) [Accessed May 24, 2018]
22. Tahir MA, Cheema A, Tareen S: Frequency of hepatitis-B and C in patients undergoing cataract surgery in a tertiary care centre. **Pak J Med Sci** **31**:895–898, 2015
23. Tillmann HL: Hepatitis C virus core antigen testing: role in diagnosis, disease monitoring and treatment. **World J Gastroenterol** **20**:6701–6706, 2014
24. Tokars JJ, Bell DM, Culver DH, Marcus R, Mendelson MH, Sloan EP, et al: Percutaneous injuries during surgical procedures. **JAMA** **267**:2899–2904, 1992
25. Villani C, Conte S, Chiozzi F, Iandolo C, Persiani P:

- Prevalence of hepatitis B and hepatitis C in an orthopaedics and traumatology ward. **Chir Organi Mov** 86:167–173, 2001
26. Wallis GC, Kim WY, Chaudhary BR, Henderson JJ: Perceptions of orthopaedic surgeons regarding hepatitis C viral transmission: a questionnaire survey. **Ann R Coll Surg Engl** 89:276–280, 2007
27. Weber P, Eberle J, Bogner JR, Schrimpf F, Jansson V, Huber-Wagner S: Is there a benefit to a routine preoperative screening of infectivity for HIV, hepatitis B and C virus before elective orthopaedic operations? **Infection** 41:479–483, 2013

Disclosures

Kevin Kallmes works for and owns equity in Superior Medical Experts.

Author Contributions

Conception and design: ES Nussbaum, Kallmes, LA Nussbaum. Acquisition of data: all authors. Analysis and interpretation of data: ES Nussbaum, Kallmes, LA Nussbaum. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: ES Nussbaum. Statistical analysis: Kallmes. Study supervision: ES Nussbaum.

Correspondence

Eric S. Nussbaum: National Brain Aneurysm Center, Minneapolis, MN. lnussbaum@comcast.net.