‘‘Oops! I forgot HIV’’: Resident physician self-audits and universal HIV screening

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Medical resident education;
Qualitative

Summary
Background: Innovations are needed to increase universal HIV screening by primary care providers. One potential intervention is self-audit feedback, which describes the process of a clinician reviewing their own patient charts and reflecting on their performance.
Methods: The effectiveness of self-audit feedback was investigated using a mixed methods approach. A total of 2111 patient charts were analyzed in a quantitative pre-post intervention study design, where the intervention was providing self-audit feedback to all internal medicine residents at one institution through an annual chart review. Qualitative data generated from the subsequent resident focus group discussions explored the motivation and mechanism for change using a knowledge—attitude—behavior framework.

Abbreviations: FGD, focus group discussion; PGY, post-graduate year; UTD, up-to-date.
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Introduction

Universal HIV screening of all American adults <65 years old offers important individual and public health benefits [1,2]. Diagnosis is the first step toward effective treatment [3,4] and can also decrease transmission rates through viral suppression and behavioral risk reduction [5–7]. However, approximately 20% of Americans living with HIV are unaware that they are infected [8]. The United States National HIV/AIDS Strategy aims to halve this number by 2015 [9].

Despite clear benefits and national goals, only 60% of U.S. general internists reported adopting universal HIV screening, most of which takes place in clinical settings [10,11]. Many providers remain unaware of the recommendation to screen for HIV universally [12]. Some providers are dissuaded because they find the topic awkward despite patients generally being receptive to screening [13–15]. Although the perceived barriers and facilitators to universal HIV screening have been described, interventions proven to be effective are scarce [10,13–22]. Targeting resident physicians for improvement in universal HIV screening may be particularly productive because (1) they represent the next wave of practicing physicians, and (2) they are more likely to successfully integrate guidelines adopted during residency into their practice [16,23].

This study aimed to evaluate the effectiveness of self-audit feedback as a mechanism for improving clinician-driven universal HIV screening among internal medicine residents at a single training program. Self-audit feedback describes a process whereby a healthcare provider performs a standardized chart review of his/her patient panel. The exercise provides immediate feedback on the provider’s practice habits. Self-identified shortcomings may motivate changes in practice patterns [24]. To the best of our knowledge, only two other studies incorporated physician feedback on HIV screening, and their interventions bundled this feedback with other quality improvement efforts [19,25]. Therefore, this is the first study to (1) use a self-audit mechanism and (2) evaluate the isolated effect of feedback on universal HIV screening. A mixed methods approach was chosen: a quantitative pre-post intervention design captured changes in HIV screening performance over a one-year period, and a qualitative analysis of focus group discussions among residents examined their motivation and mechanism of change. Residents serve a predominantly white, rural-to-suburban population with an estimated HIV prevalence of 0.2% [26].

Material and methods

Study participants and chart review data collection

The study used data on all residents who completed self-audit feedback in 2010 (pre-intervention) and/or 2011 (post-intervention) and all patients <65 years old who were selected for chart review during those years. The residency program integrated HIV screening as a new topic while routinely updating an established self-audit feedback process. This existing process will be described to provide background for the intervention. All internal medicine residents with primary care panels at the University of Wisconsin participate in an annual self-audit feedback on preventive health performance for educational purposes. The training program allot one afternoon at the end of

Results: The proportion of primary care patients screened for HIV increased from 17.9% (190/1060) to 40.3% (423/1051). The adjusted odds ratio of a patient being screened following resident self-audited feedback was 3.17 (95% CI 2.11, 4.76, \(p<0.001\)). Focus group participants attributed the improved performance to the self-audit feedback.

Conclusions: Self-audit feedback is a potentially effective intervention for increasing universal HIV screening in primary care. This strategy may be most useful in settings where (1) baseline performance is low, (2) behavioral change is provider-driven, and (3) resident trainees are targeted.

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each academic year to this activity. To complete the self-audit, residents access the institution’s medical records, including notes, laboratory results, and scanned documents from outside facilities. Topics include tetanus vaccinations, cholesterol and diabetes screenings, blood pressure control, and screening for substance abuse. Patient age and gender are recorded. Residents use a standardized form to complete the chart review of 10 male and 10 female primary care patients (see Appendix for data abstraction form). They are instructed to select patients randomly from their own primary care panels, but no formal randomization method is provided. Chart review data are submitted to the internal medicine residency program; results do not factor into resident evaluations. The gender, year of training, and clinic site (university or veteran’s) is recorded for each resident.

**Intervention**

In 2010, HIV screening was added as a new item to the annual self-audit feedback. Residents were asked to record whether all patients <65 years had ever been screened for HIV. Screening could have been performed through the resident’s clinic or at another facility, as long as this was clearly documented in the medical record. Residents were not alerted to this addition prior to the chart review; therefore, data collected in 2010 represent pre-intervention rates of HIV screening. Between 2010 and 2011, residents received no additional education, and no institutional modifications in HIV screening practices were established, including consent policies. The U.S. Preventive Service Task Force issued revised HIV screening recommendations in 2013 to harmonize with the 2006 CDC guidelines [27]. Therefore, policy changes did not contribute to secular trends during the study period. The chart review was repeated in 2011, providing post-intervention data. The study design allowed patients who were up-to-date on HIV screening in 2010 to be included in the post-intervention chart review.

**Statistical analysis**

The odds ratios for patients being screened for HIV before and after intervention were calculated using a mixed-effects generalized linear model. The independent variable of interest was the chart review year (indicator variable for post-intervention vs. pre-intervention). Other independent variables included patient age, patient gender, resident gender, patient—resident gender concordance, resident year of training, and clinic site. Training year was treated as categorical and modeled using indicator variables. All variables were dichotomous except patient age, which was continuous. To account for clustering of HIV screening performance among residents, a random effect term for resident was included. To examine whether the effect of self-audited feedback was specific to HIV screening performance, parallel mixed-effects models were run to estimate the odds of being up-to-date on other preventive services. Statistical analyses were conducted using SAS version 9.1 (Cary, NC).

**Focus group discussions**

Focus group discussions (FGD) were conducted among residents after the post-intervention chart review to assess reasons for changes in HIV screening rates. All internal medicine residents with primary care clinics in the training program at the time were eligible; however, second- and third-year residents were more actively recruited because they had experienced at least one chart review. Participants were contacted via electronic mail and announcements at residency meetings. Residents were made aware that the FGDs were to discuss their experiences with HIV screening but not explicitly the self-audit feedback. Four to six residents participated in each one-hour FGD during the winter of 2011—2012. A recent graduate of the residency program (C.K.) led the discussion using a standardized guide with probing questions for clarification. The guide was informed by (1) a knowledge—attitude—behavior framework for physician adherence to guidelines, (2) previous studies on physician barriers to HIV screening, and (3) informal discussions with residents [10,14,17,18,20,28]. To understand what led to changes in HIV screening performance, residents were asked the following: “According to the annual chart review, HIV screening has gone up quite a bit — almost doubled. How did you do it, and what motivated you?” Thematic saturation was achieved after 3 FGDs. All FGDs were audio recorded, transcribed verbatim, de-identified, and thematically analyzed using NVivo version 9 (QRS International, NC).

Qualitative analysis was accomplished using a hybridized inductive and deductive approach in 2012 [29,30]. A priori deductive thematic codes were derived from the knowledge—attitude—behavior framework for physician non-adherence to guidelines [28]. Two investigators (M.B. and J.B.) analyzed the first transcript and generated inductive thematic codes that were specific.
to HIV screening. The inductive, HIV-specific codes were then embodied into the broader knowledge—attitude—behavior deductive codes. Two investigators (M.B. and C.K.) used this hybridized schema to independently code all three transcripts line-by-line. Inter-rater reliability was 95%. The main themes were discussed by the investigators and were established after a consensus was reached. The University of Wisconsin Health Sciences Institutional Review Board approved this mixed methods study and waived the need for written informed consent.

Results

Chart review

The residents reviewed 2779 patient charts. Of these, 668 charts were excluded because of age, leaving a total of 2111 patient charts included in the study: 1060 were included in the pre-intervention year and 1051 were included in the post-intervention year. Of the residents that contributed data, 71 were in the pre-intervention year and 69 were in the post-intervention year. The total number of patient charts was greater than 99% of the expected value (2779 versus 2800), and no missing data were found in the independent variables. HIV screening information was unavailable on 20 (<1%) patients. Patient age and gender, as well as resident training year, gender, and clinic site, did not substantially change over the study period (Table 1).

The proportion of patients screened for HIV increased from 17.9% (190/1060) to 40.3% (423/1051) following self-audited feedback. In the post-intervention year, 6.6% (69/1051) of patients refused screening, and it went unaddressed in the remaining 53.1% (559/1051). After adjusting for patient- and resident-level characteristics and accounting for patient clustering by resident, the odds of a patient being screened for HIV following self-audited feedback was three-fold higher than before (adjusted OR 3.17, p < 0.001, Table 2). The only other variable independently associated with a change in HIV screening rate was patient age. For every year increase in patient age, a 4% reduction was found in the adjusted odds of being up-to-date on HIV screening (p < 0.001, Table 2).

We performed 2 post hoc analyses to further describe resident behavior change. First, we limited the analysis to data contributed by residents who were in training for both chart review years (the PGY1 and PGY2 classes of the pre-intervention year). The results did not meaningfully change (Table 2). Second, we calculated the proportion of residents who adopted HIV screening into their practice for each year, as defined by having a higher percentage of chart review patients screened for HIV than the pre-intervention study average [24]. Calculating this proportion allowed us to better assess if the improvement was due to a few residents who drastically increased HIV screening or a more broad response from the residents. In the pre-intervention year, 49.3% (35/71) of residents met our definition of adopting HIV screening. In the post-intervention year, 78.3% (54/69) residents adopted HIV screening. Therefore, the improvement in percentage of patients screened for HIV was due to a broad shift in resident behavior rather than a drastic change among a few individual physicians.

Performance of all other preventive services remained higher than HIV screening, ranging from 73.9% to 97.4% (Table 3). The only other preventive health activity that differed following the intervention was tetanus vaccination (OR 2.05, p = 0.005, Table 3). We believe this was in response to a local pertussis outbreak at which time the use of the tetanus—diptheria—acellular—pertussis vaccine was increased (Safdar, personal communication on 4/03/2013).

Focus group discussions

Fifteen of 74 (20.3%) eligible internal medicine residents participated in the FGD. All but one had previously participated in the chart reviews. Eleven of the 15 (73.3%) residents explicitly stated the

Table 1  Patient and medical resident characteristics.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Patient-level characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>1060</td>
<td>1051</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>44, SD 0.4</td>
<td>45, SD 0.4</td>
</tr>
<tr>
<td>Female</td>
<td>517, 48.8%</td>
<td>519, 49.4%</td>
</tr>
<tr>
<td>Resident-level characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>71</td>
<td>69</td>
</tr>
<tr>
<td>Female</td>
<td>29, 40.9%</td>
<td>35, 50.7%</td>
</tr>
<tr>
<td>Training year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGY-1</td>
<td>27, 38.0%</td>
<td>22, 32.0%</td>
</tr>
<tr>
<td>PGY-2</td>
<td>22, 31.0%</td>
<td>24, 34.8%</td>
</tr>
<tr>
<td>PGY-3</td>
<td>22, 31.0%</td>
<td>23, 33.2%</td>
</tr>
<tr>
<td>Clinic site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University</td>
<td>39, 54.9%</td>
<td>41, 59.4%</td>
</tr>
<tr>
<td>Veterans</td>
<td>32, 45.1%</td>
<td>28, 40.6%</td>
</tr>
</tbody>
</table>

self-audited feedback was the reason for increasing HIV screening in their patients. Prior to the self-audit, some residents were unaware of universal HIV screening guidelines: "[W]hen we did the chart review, I didn’t even know I was supposed to be asking about that. Just knowing the knowledge I should be screening for HIV helped increase my rates." Others were generally aware of the guideline, but not the details. One resident stated, "I knew the recommendation, but the chart review really solidified it for me." She said that the self-audit feedback prompted her to read the 2006 CDC

### Table 2  Odds ratio of a patient being screened for HIV given the following characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unadjusted OR main analysis (95%CI)</th>
<th>Adjusted OR(^a) main analysis (95% CI)</th>
<th>Adjusted OR(^b) post hoc analysis(^c) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-intervention year, 2011 (vs. pre-intervention year, 2010)</td>
<td>3.08 (2.53, 3.77)</td>
<td>3.17 (2.11, 4.76)</td>
<td>6.25 (2.84, 13.75)</td>
</tr>
<tr>
<td>Additional year of patient age</td>
<td>0.97 (0.96, 0.97)</td>
<td>0.96 (0.96, 0.97)</td>
<td>0.96 (0.95, 0.97)</td>
</tr>
<tr>
<td>Female patient (vs. male)</td>
<td>1.01 (0.84, 1.22)</td>
<td>0.88 (0.69, 1.11)</td>
<td>0.78 (0.58, 1.04)</td>
</tr>
<tr>
<td>Female resident (vs. male)</td>
<td>0.94 (0.78, 1.14)</td>
<td>0.83 (0.55, 1.26)</td>
<td>1.00 (0.59, 1.70)</td>
</tr>
<tr>
<td>Patient—resident gender concordance (vs. non-concordance)</td>
<td>1.29 (1.06, 1.58)</td>
<td>1.05 (0.83, 1.32)</td>
<td>1.04 (0.79, 1.39)</td>
</tr>
<tr>
<td>Training year of resident</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGY-1</td>
<td>0.87 (0.69, 1.09)</td>
<td>0.91 (0.55, 1.49)</td>
<td>2.25 (0.77, 6.60)</td>
</tr>
<tr>
<td>PGY-2</td>
<td>1.10 (0.87, 1.39)</td>
<td>0.95 (0.57, 1.57)</td>
<td>1.18 (0.57, 2.45)</td>
</tr>
<tr>
<td>PGY-3</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Veterans clinic site (vs. university)</td>
<td>0.57 (0.47, 0.70)</td>
<td>0.76 (0.50, 1.15)</td>
<td>1.08 (0.62, 1.89)</td>
</tr>
</tbody>
</table>

\(^a\) Odds ratios were adjusted for all other characteristics included in the table and patient clustering by resident within each year was accounted for using a random effect.

\(^b\) The post hoc sensitivity analysis was restricted to chart review data collected by residents who were in training both years (the PGY-1 and PGY-2 class of the pre-intervention year). This is in opposition to the main analysis, which included data contributed by all residents in the program (includes PGY-3 trainees in the pre-intervention year who graduated before the post-intervention year and PGY-1 trainees in the post-intervention year who were not present in the pre-intervention year). Of note, graduating PGY-3 residents’ primary care patients are transitioned to incoming PGY-1 residents. Therefore, the patient populations for both pre- and post-intervention years are stable.

### Table 3  The percent of patients up-to-date (UTD) on preventive services in the pre- and post-intervention years.

<table>
<thead>
<tr>
<th>Preventive service(^a)</th>
<th>Percent of patients UTD in pre-intervention year (2010)</th>
<th>Percent of patients UTD in post-intervention year (2011)</th>
<th>Absolute percentage point change (2011–2010)</th>
<th>Adjusted OR(^b) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV screen</td>
<td>17.9</td>
<td>40.3</td>
<td>22.4</td>
<td>3.17 (2.11, 4.76)</td>
</tr>
<tr>
<td>Tobacco</td>
<td>85.2</td>
<td>92.3</td>
<td>7.1</td>
<td>2.05 (1.25, 3.36)</td>
</tr>
<tr>
<td>Blood pressure controlled</td>
<td>83.9</td>
<td>81.2</td>
<td>−2.7</td>
<td>1.08 (0.66, 1.75)</td>
</tr>
<tr>
<td>Cholesterol screen</td>
<td>81.3</td>
<td>81.5</td>
<td>0.2</td>
<td>1.20 (0.75, 1.92)</td>
</tr>
<tr>
<td>Diabetes screen</td>
<td>73.9</td>
<td>76.1</td>
<td>2.2</td>
<td>1.44 (0.85, 2.43)</td>
</tr>
<tr>
<td>Alcohol addressed</td>
<td>97.4</td>
<td>97.4</td>
<td>0.0</td>
<td>1.07 (0.53, 2.17)</td>
</tr>
</tbody>
</table>

\(^a\) Preventive service recommendations were based on those of the following organizations: CDC; Advisory Committee on Immunizations Practices; Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults; U.S. Preventive Services Task Force.

\(^b\) Odds ratios were adjusted for patient age, patient gender, resident gender, patient—resident gender concordance, training year of resident, and clinic site. Patient clustering by resident within each year was accounted for using a random effect.

guideline and learn about the recommended frequency of HIV screening. By the end of the study period, focus group participants felt that they and their peers understood the 2006 CDC guidelines recommending universal HIV screening.

The self-audit feedback provided two types of motivation for improving HIV screening. Some residents felt that their low rate of HIV screening, independent of any other information, was sufficient enough to warrant an improvement. One said, "It was good enough just to see we weren’t checking. I think most of us are motivated to be meeting all of the standards." Others noticed the stark contrast in HIV screening performance relative to other preventive services. One resident explained that his motivation was "seeing that my rates were so bad. That was by far my weakest category." Another remembered filling out the chart review and thinking, "Oh, wait. Oops! I forgot HIV... I don’t normally miss [other preventive services]."

Many residents described an internal resolve to change their behavior following their self-audit feedback. One remarked, "I was going to commit to change... because I was so embarrassed." Another recalled when HIV screening was introduced to the chart review "and not doing a very good job at it. I thought 'OK, I am going to be 100% compliant with this [recommendation].'"

A positive attitude to improving their individual HIV screening performance spurred individualized practice changes among residents. Residents reported developing introductory phrases to tell patients how experts recommended universal HIV screening as a standard preventive service. Most residents also modified their electronic medical record templates for clinic notes to include HIV screening in the preventive health section. Changes were individualized, rather than institution-driven, and embedded within a resident's systematic practice. Following self-audited feedback, many residents felt that they were successfully integrating universal HIV screening into their continuity clinic experiences (e.g., "It's become part of my practice now.").

Discussion

Internal medicine residents doubled their rates of universal HIV screening in their primary care practice within one year of self-audited feedback. This increase was independent of other patient- and resident-level characteristics. The effect of self-audited feedback appeared specific to HIV screening rather than an overall increase in preventive services. The ability to detect an increase in tetanus immunization, which we attribute to a local pertussis outbreak, demonstrates that the chart review was able to capture small shifts in screening among preventive services with higher compliance rates. Thus, the finding of stable performance in other preventive measures is likely true and does not reflect a lack of statistical power. The majority of residents incorporated HIV screening into their practice; improvement was not due to momentous change from a few residents.

Qualitative findings provide evidence that self-audit feedback drove the increase in HIV screening. Residents directly attributed most of their improvement to the chart review. Furthermore, they described a mechanism of change consistent with a theoretical knowledge—attitude—behavior framework for physician adherence to guideline recommendations [28]. Specifically, the self-audit feedback led residents to learn more about the 2006 CDC guidelines, which resulted in developing positive attitudes toward the recommendation and behavioral modifications to enhance HIV screening. Lastly, the addition of HIV screening to the self-audited feedback is a minimal and feasible intervention that should be sustained easily. This strategy was integrated into a previously existing forum for practice improvement and continues to be an included topic. The fact that the self-audit was an established and expected entity provided a natural control in the pre-intervention phase.

The study findings are consistent with other reports showing that audit and feedback improves physician performance across a number of different measures and increases routine HIV screening rates when included as a part of multifaceted interventions [19,24,25,31]. However, this study is unique in that (1) self-audit and feedback was used in isolation to improve universal HIV screening, and (2) the magnitude of change was much higher than expected. Whereas audit and feedback have been associated with an average increase in a desired practice by 4.3 absolute percentage points, this study reports an increase of 22.4 absolute percentage points in HIV screening [24]. One explanation for the enhanced effect is that the pre-intervention screening rate was very low; baseline performance is inversely associated with the effectiveness of audit and feedback [24]. Residents who independently chose to increase HIV screening, rather than being informed of a program-wide initiative, may also have contributed to the observed improvement because self-directed initiatives have been demonstrated to be more effective in eliciting practice change [24,25]. The self-audit feedback intervention, as opposed to external audits, may have
been particularly effective in fostering this type of change by endowing the residents with a sense of ownership and internal resolve. Lastly, residents, in particular, may be more accepting of change than attending physicians because they are still establishing their outpatient practice style.

Audit and feedback approaches to change physician screening practices can be most useful when low baseline screening rates exist, practice change is provider-driven, and physicians are new to practice [24,31]. All of these three features were present in this study. We identified only one other study with a high observed increase in HIV screening following audit and feedback, but this study included HIV screening as one component of a multifaceted intervention [25].

This study is limited by its pre-post design and lack of a separate control group. A causal interpretation between self-audited feedback and increased HIV screening performance cannot be made. However, the high specificity of the quantitative findings and qualitative focus group analyses suggest that the self-audit feedback was responsible for motivating residents to improve their HIV screening practices. Improved screening rates could represent statistical regression to the mean. However, we believe this is unlikely because regional screening rates are lower than 40% and the qualitative data suggests a true change in practice [32]. The chart audits were self-performed and are limited by potential reporting bias: residents were asked to select patients for the chart review at random without an oversight mechanism to ensure this. In both years, residents were able to see the chart review template minutes before selecting patients. Although residents could have purposefully chosen patients who had been screened for HIV, this bias would likely have occurred, if at all, to the same degree in the pre- and post-intervention periods. Thus, the observed magnitude of improvement in HIV screening is likely accurate and was corroborated by the findings from the FGDs. The study was unable to ascertain whether high-risk patients were screened according to CDC recommendations because the chart review only asked residents to indicate whether their patients had ever been screened for HIV. We would like to note that while we used a published method for calculating the proportion of providers adopting practice change, our definition was lenient because of the low baseline rate of HIV screening. This post hoc analysis still answers the intended question of whether improvement (but perhaps not full adoption) was due to behavior change among a few or more residents.

Limitations also exist for the qualitative assessment. FGD data may not reflect the full spectrum of resident experience with the self-audit intervention. Those who did not integrate HIV screening into their practice due to less skill or lack of interest may have been least apt to participate in the FGDs. Therefore, more neutral or negative experiences may not have been captured.

Despite an observed doubling of HIV screening, the percent of primary care patients screened for HIV following resident self-audit and feedback remained relatively low at 40%. Approximately 45% of Americans have ever had an HIV test, with lower testing rates observed in lower prevalence, rural communities [8,33]. The Midwest has the lowest HIV screening performance in the United States even after adjusting for patient demographics and HIV risk factors; approximately 30% of inhabitants have ever undergone screening [33]. Therefore, given the geographic region in which this intervention occurred, screening 40% of primary care patients for HIV is noteworthy. However, further improvement should be made to bring universal HIV screening on par with other preventive services. Lags may continue to exist because of (1) low prioritization by providers and (2) patient resistance to HIV screening stemming from social stigma and self-perceived low risk [34]. This research suggests that coupling self-audited feedback with other interventions addressing the reasons for continued lags could be a potentially useful strategy for residents. The self-audit feedback approach would be particularly feasible in settings where HIV screening could be integrated into existing feedback mechanisms.

Conclusions

Internal medicine residents doubled HIV screening among their primary care patients following self-audit feedback. Qualitative data suggested that this feedback enhanced knowledge and attitudes, ultimately leading to changes in physician behavior. The magnitude of improvement was greater than anticipated and may indicate that feedback is particularly effective when (1) baseline performance is low, (2) behavioral change is provider-driven, and (3) resident trainees are targeted. Despite clear gains, further work is needed to bring HIV screening performance up to the level of other preventive services.

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Competing interests

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Ethical approval

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jiph.2014.08.010.

References


