ORIGINAL RESEARCH PAPERS

Description of an independently developed quality assessment tool to meet emergency department credentialing and Emergency Ultrasound Fellowship Accreditation Council guidelines

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ABSTRACT

Background: Quality assurance (QA) review is essential to any point-of-care ultrasound (POCUS) program that credentials emergency clinicians or hosts an Emergency Ultrasound Fellowship Accreditation Council (EUFAC) accredited fellowship. Commercially designed QA solutions exist but may not be accessible to all programs due to budgetary or institution-specific administration constraints.

Objectives: The authors aimed to develop a robust, standalone, HIPAA-compliant POCUS QA database which satisfies both credentialing requirements and EUFAC review goals.

Methods: An indexed, searchable electronic QA database was developed using Google workspace. The database was inspected reviewer disagreement trends that led to feedback at the individual and departmental level and was used to satisfy QA review requirements for ultrasound fellows.

Results: Since deployment of the database in July 2021, 2742 studies have undergone QA review out of approximately 15,000 studies performed (18.3%). Reviewers disagreed with some portion of the interpretation in 848 (24.8%) exams, most commonly abdominal aortic aneurysm evaluation (n = 45 exams, 31.1%) and basic echocardiography (n = 1203 exams, 27.9%). Disagreement was least common for male genitourinary exams (n = 19 exams, 0%) and advanced echocardiograms (n=57, 15.8%), likely reflecting operator experience. For 209 (7.6%)

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studies, feedback to the clinicians was warranted and delivered via direct communication. This process has resulted in department-level education in consistently deficient areas.

Conclusion: We present our lightweight, easily reproducible alternative to commercial POCUS QA solutions that has led to targeted feedback and department-level education while also satisfying accreditation requirements.

Key words: Point-of-care ultrasound, quality assurance, quality improvement, database, middleware

Introduction

Point of care ultrasound (POCUS) is a key element of the practice of emergency medicine (EM). The successful management of an emergency ultrasound (EUS) POCUS program relies heavily on ensuring the competency of its clinicians and the quality of their ultrasound studies. A program can include clinicians at all levels of training including resident physicians, ultrasound fellows, non-physician clinicians, and attending physicians with varying backgrounds in POCUS from residency training to fellowship. This range of experience in POCUS use has led to different benchmarks used to claim proficiency for procedural credentialing [1]. Continuous quality management of an EUS program is essential for credentialing, risk management, and tailored educational interventions. Quality management should include quality assessment (QA) and quality improvement (QI) components. QA is intended to focus on review of an individual clinician's use of ultrasound, while QI should provide timely feedback to clinicians based on QA findings [2]. EUS programs vary widely in their methods of ensuring clinician proficiency, frequently mandating a certain number of completed scans with a subset of positives however the exact number is highly variable [1].

While there are many accepted ways to determine proficiency, by convention trainees are required to complete a target number of reviewed exams and then a percentage of future scans are reviewed for continuing QA [3]. The American College of Emergency Physicians (ACEP) clinical guideline proposes 10% as a reasonable goal [4]. ACEP's Clinical Ultrasound Accreditation Program (CUAP), which aims to establish minimum standards of quality for EUS programs, also requires a formalized QA and QI process [5]. As EUS programs grow, a system to provide this data to the EUS director and any other interested parties is necessary. An ideal system would also provide timely feedback to individual clinicians and track patterns in QA results that might trigger the need for more training at the departmental level. Several commercially available software solutions such as Q-path (*Telexy Healthcare, Port Coquitlam, BC, Canada*) integrate image archival and report generation while also including the ability to perform QA review, give feedback, and track the number and type of exams a provider performs [2,6]. While convenient, not all practice settings have access to these out-of-the-box programs due to budgetary constraints or decisions made at hospital or health system level. Groups that staff different hospital facilities and use different ultrasound machines or middleware face added difficulty with credentialing and QA data capture due to the common lack of interoperability between electronic medical record platforms (EMRs), middleware, and archival programs that would facilitate QA review.

Our academic emergency medicine group staffs two hospitals within two separate health systems. Both use the AGFA Enterprise Imaging PACS (*Agfa-Gevaert N.V., Mortsel, Belgium*) for image archival, but image databases are separate. QA performed within AGFA is not searchable which hinders analysis of trends and needs in QI and credentialing. It also lacks functionality for tracking the EUFAC-mandated requirements for QA review by ultrasound fellows during training [7]. Here we describe a QA database system conceived, designed, and implemented within our department to achieve our QA and QI goals when the available commercial software tools were lacking.

Methods

Software

Our system uses the widely available cloud-based application Google Forms to populate QA data and feedback into Google Sheets spreadsheets (*Google LLC, Mountain View, CA*) to maintain data on reviewed POCUS studies. Both are available as part of the Google Workspace Suite which is licensed through our institution. This has the added benefit of ensuring that all applications and cloud storage drives are HIPAA-compliant, all patient information is kept secure and confidential behind institutional two-factor authentication security. Google Workspace Suite offers a familiar user interface, allows multiple users to collaborate in real time on a single document, and backs up changes continuously. It also operates out of most modern web browsers allowing users the flexibility to work from any location.

Data capture workflow

Data capture begins during the QA process when reviewers enter scan information into the Google Form such as medical record number, scanner and attending names, scan date, scan type(s), scanner's findings and impressions, and whether reviewers agreed or disagreed with the scanner's interpretation (Figure 1). This form also has options to label studies as particularly interesting or requiring a follow-up call to the patient. Each form submission is imported into the Google Sheet as a single row.

Data validation at the time of data entry allows for more streamlined searching of results downstream. The names of the scanner – often a resident physician or non-physician provider – and attending physician are populated from lists maintained in the same file containing the resultant QA data, and the form will only accept names that exactly match names on those lists. The size of our group and rotating nature of academic staffing leads to the need for a Javascript routine to update the form with this information to avoid tedious manual updates and potential transcription errors.

POCUS exam types are specified via checkboxes allowing the reviewer to review multiple different exam types performed within one study, such as a lower extremity deep vein thrombosis (DVT) exam with an echocardiogram for dyspnea or a gallbladder exam with a renal exam for right flank pain.

Reviewers then label the study interpretation as true-positive, true-negative, false-positive, false-negative, or technically limited and assess adequacy of documentation for billing in the EMR. There is a space to provide feedback for image acquisition and study interpretation, and to label whether individual feedback was provided to the clinicians by the reviewer. Lastly, there is a marker to flag studies of high educational value for presentations.

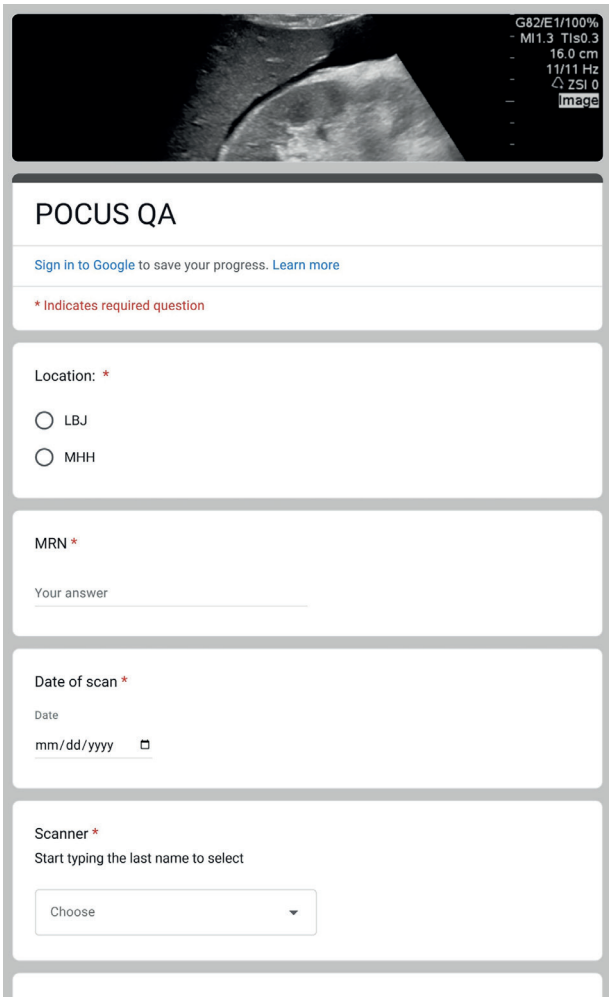


Figure 1. Partial sample of QA intake form.

Database management

Several separate sheets are used to track specific data. In this section we describe the various sheets and their uses. Central to the maintenance of our database system is the use of queries and google apps scripting. Queries are functions within the google sheets application similar to the cell functions found in Microsoft Excel that use a combination of structured query language (SQL), spreadsheet formula syntax, and cell references to return data. Certain functions require more intensive automation such as updating the scanner list using Apps Script, a Javascript-based development platform that was mentioned previously. Conveniently, this script is run within the database sheet itself to avoid the need to switch between Google Forms and Google Sheets.

Sheet "Data"

This sheet is a copy of the raw form responses upon which all data manipulation is done (Figure 2). Duplicating the form responses to a separate sheet for management provides a backup should any fields be accidentally altered. Each row is a single submission on the google form and each column is a field on the form.

Sheet "Query"

Here users have the option to retrieve exams matching the exact criteria specified in the search (Figure 3). Exams can be selected based on type of ultrasound study, whether there was reviewer agreement with scanner interpretation, or specific scanner or attending. Additionally, the user can filter exams from any desired date range. Finally, the user can retrieve exams containing interesting images as flagged by the QA reviewer on the intake form. The form then presents the list of exams that match all the criteria in table format along with a count of scans returned and the subset marked as inaccurately interpreted upon QA review.

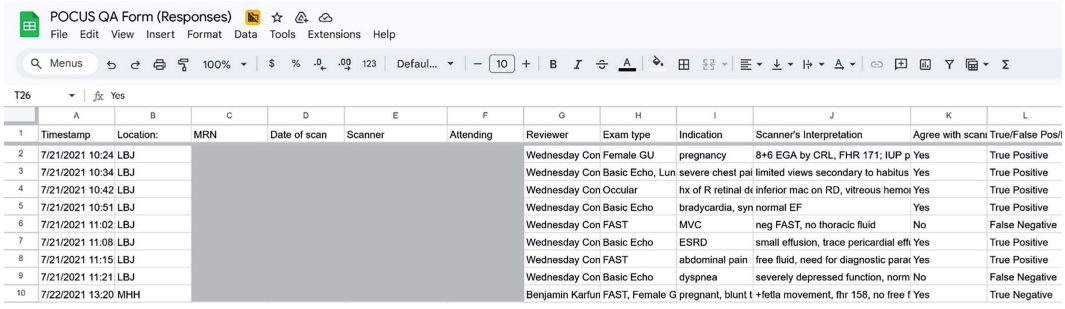
This simple yet powerful function can track patterns that might be interesting to QA directors such as trends of incorrect interpretation stratified by clinician or exam type. This might prompt QI activities for individuals or at the department level.

Sheet "Reviewer Counts by Month"

We use this database to meet EUFAC requirements for QA completion by fellows and to track overall department QA goals. This sheet displays an up-to-date list of EUS group members who perform QA and their current review count totals by month with a sub-section for fellows to better track their graduation requirements. This allows for rapid demonstration of metrics outlined by accreditation bodies such as CUAP.

Data Provenance"

Data traceability and auditing are made simpler using the built-in tools that Google Sheets is equipped with, such as automatic version tracking and tracked changes at the cell level. Administrators of the database can view recent changes and track which users modified specific cells or formulas. When combined

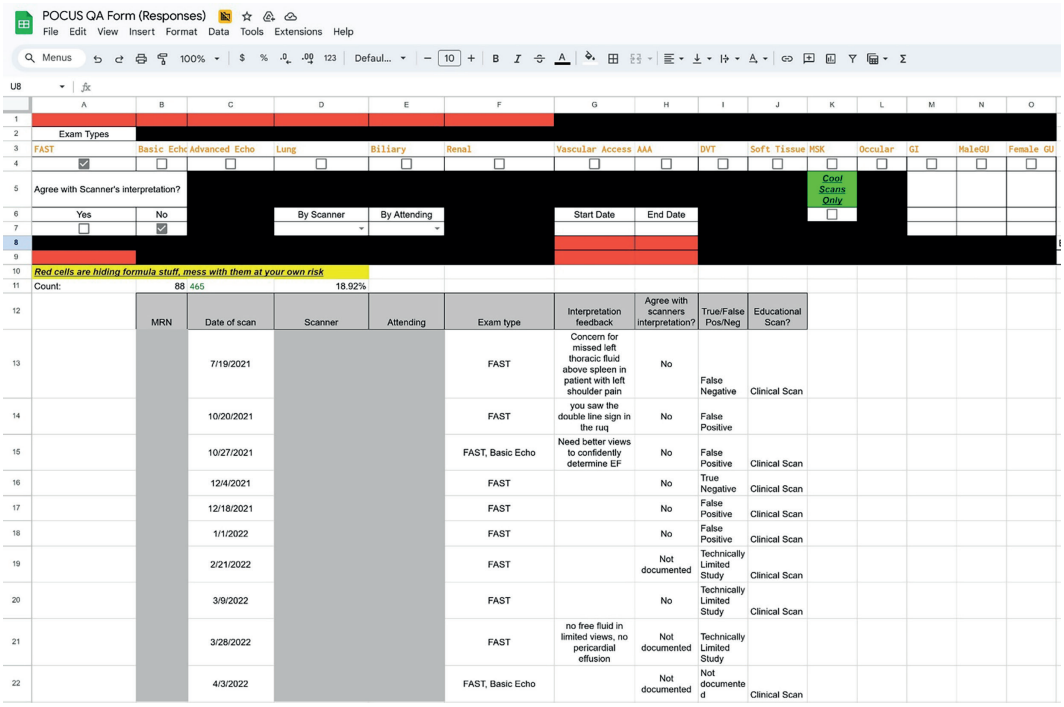

POCUS QA Form (Responses)

File Edit View Insert Format Data Tools Extensions Help

T26 Yes

	A	B	C	D	E	F	G	H	I	J	K	L
1	Timestamp	Location:	MRN	Date of scan	Scanner	Attending	Reviewer	Exam type	Indication	Scanner's Interpretation	Agree with scan	True/False Pos/
2	7/21/2021 10:24	LBJ					Wednesday Con	Female GU	pregnancy	8+6 EGA by CRL, FHR 171; IUP p	Yes	True Positive
3	7/21/2021 10:34	LBJ					Wednesday Con	Basic Echo, Lun	severe chest pai	limited views secondary to habitus	Yes	True Positive
4	7/21/2021 10:42	LBJ					Wednesday Con	Occular	hx of R retinal de	inferior mac on RD, vitreous hemo	Yes	True Positive
5	7/21/2021 10:51	LBJ					Wednesday Con	Basic Echo	bradycardia, syn	normal EF	Yes	True Positive
6	7/21/2021 11:02	LBJ					Wednesday Con	FAST	MVC	neg FAST, no thoracic fluid	No	False Negative
7	7/21/2021 11:08	LBJ					Wednesday Con	Basic Echo	ESRD	small effusion, trace pericardial eff	Yes	True Positive
8	7/21/2021 11:15	LBJ					Wednesday Con	FAST	abdominal pain	free fluid, need for diagnostic para	Yes	True Positive
9	7/21/2021 11:21	LBJ					Wednesday Con	Basic Echo	dyspnea	severely depressed function, norm	No	False Negative
10	7/22/2021 13:20	MHH					Benjamin Karfun	FAST, Female G	pregnant, blunt t	+fetla movement, fhr 158, no free f	Yes	True Negative

Figure 2. Sheet "Data". Raw form responses are maintained here. Areas in gray are redacted for patient privacy.


POCUS QA Form (Responses)

File Edit View Insert Format Data Tools Extensions Help

Exam Types

FAST	Basic Echo	Advanced Echo	Lung	Biliary	Renal	Vascular Access	AAA	DVT	Soft Tissue	MSK	Occular	GI	MaleGU	Female GU
☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Agree with Scanner's interpretation?

Cool Scans Only ☐

Yes	No	By Scanner	By Attending	Start Date	End Date
☐	☑				

Red cells are hiding formula stuff, mess with them at your own risk

Count: 88 465 18.92%

MRN	Date of scan	Scanner	Attending	Exam type	Interpretation feedback	Agree with scanners interpretation?	True/False Pos/Neg	Educational Scan?
	7/19/2021			FAST	Concern for missed left thoracic fluid above spleen in patient with left shoulder pain	No	False Negative	Clinical Scan
	10/20/2021			FAST	you saw the double line sign in the ruq	No	False Positive	
	10/27/2021			FAST, Basic Echo	Need better views to confidently determine EF	No	False Positive	Clinical Scan
	12/4/2021			FAST		No	True Negative	Clinical Scan
	12/18/2021			FAST		No	False Positive	Clinical Scan
	1/1/2022			FAST		No	False Positive	Clinical Scan
	2/21/2022			FAST		Not documented	Technically Limited Study	Clinical Scan
	3/9/2022			FAST		No	Technically Limited Study	Clinical Scan
	3/28/2022			FAST	no free fluid in limited views, no pericardial effusion	Not documented	Technically Limited Study	
	4/3/2022			FAST, Basic Echo		Not documented	Not documented	Clinical Scan

Figure 3. Sheet "Query". Red cells contain formula calculations necessary to display search results. Checkboxes, dropdown fields, and free text cells can be modified by users to determine search results.

with the timestamp information provided with each QA review form submission, the trail of review is readily auditable from start to finish.

Data Protection and Compliance

By necessity, this database maintains protected health information (PHI) and thus must be secured to maintain HIPAA compliance. Commercially-available software packages that include both image archival and QA functionality also include technical and legal data protection measures that can be tailored to fit local regulations, making them suitable for many markets. EUS programs without access to these programs may need to develop workarounds such as the database described in this article, however the same regulatory standards must be met. The advantage of using the Google Workspace suite lies with the data security protocols that are built in. A brief summary is included here.

All data is encrypted at rest within Google's servers after first being decentralized into several "chunks", each requiring multiple layers of encryption keys to access. An attacker would need both a key to each individual chunk, the wrapping key that secures the chunk key, and to compromise Google's key management service which authenticates each data request against an access control list (ACL). This ACL is, in practice, configured by the database administrator by managing the spreadsheet sharing permissions. Thus, access to view and edit the data can be limited to only individuals with the need for it such as a core group of faculty reviewers. Data in transit (between the browser used to access the database) and Google servers is encrypted using 2048-bit Rivest-Shamir-Adleman (RSA) cryptographic keys or P-256 Elliptic Curve Digital Signature Algorithm (ECDSA) certificates, per Google's own documentation [8]. These software-level PHI safeguards are part of Google's responsibilities as outlined in the Business Associate Agreement (BAA) which is put in place at the time of purchase of the Google Workspace suite by our institution.

The database is secured with the same 2-factor authentication method that secures many services at

Table 1. QA Review Disagreement by Exam Type.

	Total	% of Total	Disagree	% Disagree
FAST	389	11.39%	90	23.14%
Basic Echo	1203	35.24%	336	27.93%
Advanced Echo	57	1.67%	9	15.79%
Lung	404	11.83%	101	25.00%
Biliary	345	10.11%	87	25.22%
Renal	242	7.09%	55	22.73%
Vascular Access	33	0.97%	9	27.27%
AAA	45	1.32%	14	31.11%
DVT	51	1.49%	13	25.49%
Soft Tissue	115	3.37%	30	26.09%
MSK	47	1.38%	9	19.15%
Ocular	63	1.85%	15	23.81%
GI	31	0.91%	7	22.58%
Male GU	19	0.56%	0	0.00%
Female GU	370	10.84%	73	19.73%
Total exams	3414	100.00%	848	24.84%

Abbreviations: FAST: Focused assessment with sonography in trauma; Echo: Echocardiography; AAA: Abdominal aortic aneurysm; DVT: Deep Vein Thrombosis; MSK: Musculoskeletal; GI: Gastrointestinal; GU: Genitourinary

our institution that involve PHI. Audit logs containing the date, user, and details of any data manipulation are available as part of the Google Workspace product, managed by the institutional IT department. While the database has only been active for four years, our intent is to maintain records and associated audit logs for a minimum of seven years from patient encounter date in the event of any billing inquiries and to satisfy requirements of the HIPAA Privacy Rule [9]. After this date, these records are deleted permanently.

In the event of a security compromise of the database, our institution's standard information security breach protocol would be implemented which enlists the assistance of the IT administrator to de-credential all users temporarily and sever any external connections to the database while audit logs are reviewed and the source of the breach identified. Efforts would then be made to inform any affected patients of the nature of data that was compromised and in the event of a large breach (>500 individuals), a report would be made to the Department of Health and Human Services and a local media statement would be issued in line with the HIPAA Breach Notification Rule [10].

Scan logger

Clinicians undergoing procedural credentialing may further use the logging system for the POCUS studies they perform. This is used by EM residents during their core ultrasound rotations and fellows participating in our group's EUFAC-accredited clinical ultrasound fellowship program. This scan logger tracks similar information including MRN, date, type of exam and findings. Exams not reviewed by an EUS faculty member in real time are flagged for review during asynchronous QA review sessions, allowing novice sonologists to receive feedback on scans that are performed either directly with EUS team members or independently. This functionality when integrated with the QA database can track progress towards credentialing for clinicians seeking privileges via the non-residency-based pathway employed at other institutions [11].

Results

This POCUS QA system has been employed by our academic emergency medicine group since July 2021. The department bills for approximately 500 POCUS studies per month, or 6000 studies per year. This is a conservative estimate; since individual studies may contain several exam types, comprehensive review of each individual study is needed to determine the exact number.

Prior to implementation of this system, POCUS studies were reviewed for QA on paper. This resulted in no searchable database for QI and made tracking individual clinicians' and group scan numbers highly impractical. In the 2.5-year span since deployment, 2742 studies have undergone QA review using our system out of approximately 15,000 studies performed (18.3%), above the 10% guideline proposed by ACEP [4]. Within those reviewed studies, 3414 total exams were reviewed when accounting for individual ultrasound studies that included multiple different exam types. The

breakdown of different exam types is provided (Table 1). The most frequently reviewed exam types were basic echocardiograms (n=1203, 35.2%), lung ultrasound (n=404, 11.8%) and Focused Assessment with Sonography in Trauma (FAST) exams (n=389,11.4%). The least frequently reviewed exam types included testicular (n=19, 0.6%), gastrointestinal (n=31,0.9%), and abdominal aortic aneurysm exams (n=45,1.3%).

Of the 3414 exams reviewed, reviewers disagreed with part of the interpretation in 848 (24.8%). Disagreement was most common for Abdominal Aortic Aneurysm evaluation (n = 45 exams, 14 disagreements, 31.1%) and basic echocardiography (n = 1203 exams, 336 disagreements, 27.9%). Disagreement was least common for Male GU exams (n = 19 exams, 0 disagreements, 0%) and advanced echocardiograms (n=57,9 disagreements, 15.8%), likely reflecting operator experience as discussed later.

Review of these 2742 studies resulted in 209 (7.6%) instances of feedback via email communication with the clinicians who performed the studies, though it is impossible to quantify this increase in the rate of timely feedback due to lack of records prior to system implementation.

Discussion

Prior to this workflow, QA review was performed on paper. The results were not searchable, and it is unclear how often these reviews resulted in direct feedback to individual clinicians performing these procedures. The resulting QA was not easily translated to actionable QI. This QA system has overcome limitations in combining QA results from our two distinct hospital sites to allow for a searchable database that allows for timely and specific feedback to individual clinicians, and for identification of group-wide trends that guide group-wide QI.

Use of our conceived database has provided demonstrable evidence of trends that were suspected by our group but not readily quantifiable previously. As expected, the distribution of QA results and feedback across all POCUS exam types showed that the exam types most likely to be performed by experienced bedside sonologists such as musculoskeletal or advanced echocardiography were the ones that garnered less frequent disagreement on review, an experience mirrored by other groups examining such trends [12]. The high number of disagreements for basic echocardiography is likely reflective of the fact that it is the most frequently performed exam overall and is most often performed by trainees.

During QA, studies are selected at random from the pool of studies completed within the past 30 days. This sample is therefore expected to be representative of the total collection of billed and archived ultrasound studies in the department. Based on this assumption, group-wide educational content has been tailored to include spaced repetition lectures covering how to perform POCUS exam types that are of high utility but not frequently performed by our group such as scanning for DVT (n=51, 1.5% of exams). Lecture content has included pearls and pitfalls for the most common exam types such as biliary and basic echocardiography. As usage of the database continues, formalized QI assessments can better quantify these effects on education and the QA process [13]. At this time, individualized feedback delivered by email during QA review is left to the discretion of the reviewer but usually includes comments on what improvements could be made with the imaging or interpretation and links to educational content. Future improvements planned for the database include more detailed tracking of timeliness of feedback and how instances of feedback affect that clinician's true positive/true negative rate.

Limitations

We consider our database to be novel and robust, however no database management solution is a universal fit. Though our institution uses the AGFA image archival system to view and store ultrasound images, this database was conceived in part because AGFA's intrinsic QA workflow was not compatible with our department's needs. A connection between the AGFA software and our database would be convenient, allowing users to easily view images and report QA findings in a single application, however unfortunately this capability does

not exist. Our solution does not necessarily smooth the workflow for institutions in similar positions.

Some limitations are specific to the Google Workspace platform. Our institution's information technology (IT) department configured the product to require 2-factor authentication for HIPAA-compliance. While this has worked well for our department, licensing and data security requirements vary from institution to institution. Furthermore, the use of cloud-based storage sites can be restricted on hospital networks for security reasons, making this database inaccessible unless an exception is arranged through hospital IT. This adds a layer of inconvenience that may require concerted departmental efforts and time to circumvent.

Implementation of this homegrown QA workflow resulted in frequent directed feedback for clinicians performing POCUS in our emergency departments. The technology required to produce such a workflow is free to use and readily available with Google Sheets and Google Forms if HIPAA related protected health information (PHI) is excluded from the workflow, however delivery of meaningful feedback tied to specific patient cases likely necessitates the use of PHI. Inclusion of patient identifiers such as medical record numbers necessitates paid services for HIPAA compliant data storage that may not be accessible for departments on a tight or non-expandable budget.

Finally, the data protection protocols described previously were designed to satisfy the requirements of HIPAA as this database was conceived and operates in the United States, however institutions operating under other regulatory standards would need to ensure their specific implementation is compliant with them. It is likely that when faced with a choice between a commercial product that is licensed or otherwise accredited as a piece of medical software and our internally-developed solution, most departments would prefer the former as the onus of ensuring compliance with data protection principles and regulation primarily falls on the manufacturer of the product. While we fully acknowledge this fact, we hope the description of this workaround may be helpful for EUS departments that either lack the ability to purchase a commercial product or who have already purchased one that does not meet their workflow needs as was the case for our department.

Conclusion

While many commercial solutions exist to assist in an EUS director's QA responsibilities, not all departments have access to such ready-made programs due to political or budgetary reasons. We present our conceived solution: a lightweight, user-friendly, cloud-based way to manage the quality assurance workflow of a department using the Google Office suite. Programming knowledge is unnecessary to manage the database on a day-to-day basis, however some experience with programming or knowledge of SQL and Javascript would be helpful for individuals seeking to alter or expand its functionality. Our implementation has led to changes in our educational curriculum tailored to the trends revealed by these QA data.

Article summary

1. *Why is this topic important?*
   Institutions lacking access to out-of-the-box POCUS QA software would benefit from the ability to reproduce and operate a more accessible QA database solution using software that is likely already available in a wider range of settings.
2. *What does this study attempt to show?*
   A robust standalone QA database allows a POCUS program to participate in the QI process but also satisfy emergency department credentialing requirements and EUFAC review requirements.
3. *What are the key findings?*
   At our institution, implementation of the database has led to improved feedback and education at the department level, assisted with emergency department provider credentialing, and satisfied EUFAC review requirements. The database can be easily reproduced at other institutions with access to the Google Workspace suite of products to perform the same function.
4. *How is patient care impacted?*
   POCUS is a mandatory skill for emergency clinicians and our robust, accessible POCUS QA solution enables ongoing delivery of

feedback that can raise a department's baseline skill potentially leading to avoidance of diagnostic errors, timelier diagnosis, and decreased cost to the patient through the obviation of advanced or consultative imaging.

Abbreviations

AAA: Abdominal aortic aneurysm
ACEP: American College of Emergency Physicians
CUAP: Clinical ultrasound accreditation program
DVT: Deep vein thrombosis
EMR: Electronic medical record
EUFAC: Emergency Ultrasound Fellowship Accreditation Council
EUS: Emergency ultrasound
FAST: Focused assessment with sonography in trauma
GU: Genitourinary
HIPAA: Health Insurance Portability and Accountability Act
IT: Information technology
MRN: Medical record number
PHI: Protected health information
POCUS: Point-of-care ultrasound
QA: Quality assurance
QI: Quality improvement
SQL: Structured query language

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Availability of Data and Material: The datasets generated and/or analyzed during the current study are not publicly available due to the protected health information contained therein, however a demonstration version of the database is available from the corresponding author on reasonable request so that individuals seeking to reproduce the database may explore its capabilities and duplicate it.

Ethics Approval and Consent to Participate: Not applicable

Consent for Publication Not applicable

Competing Interests: The authors declare that they have no competing interests.

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