GE HealthCare

Intelligent Protocoling

Automating protocol selection to simplify and streamline your scan-time workflow

Technical white paper

Wenyan Min
Vignesh Doraiswamy
Yaxi Shen, PhD
Franco Rupcich, PhD

Contents

02 Introduction
02 What is protocoling?
03 The current state of protocoling
04 The machine learning approach to protocoling
05 How Intelligent Protocoling works
  05 Automatic protocol suggestion and selection
06 Early evidence: Clinical evaluation
  06 Intelligent Protocoling experience – Japan
  08 Intelligent Protocoling experience – France
  09 Intelligent Protocoling experience – USA
10 Clinical and workflow improvements
10 Conclusion
11 Glossary
11 References

Introduction

The number one goal for CT providers is to provide consistent, high-quality service for every patient, every time at every facility or location.

This used to be easy, when a CT program was self-contained within a single hospital or within a small health system. As health systems and CT programs continue to grow and expand, delivering on this simple goal has become increasingly difficult. Large, complex health systems present many challenges, including high staff burden, more complex exam procedures and lack of workflow and protocol standardization. This may cause variability in radiation dose and exam quality, which pose risks to patient safety and clinical outcomes.

One method to address these challenges is to automate CT protocoling to enable effortless CT workflow and ensure patient scans are performed safely and effectively.

Protocoling is the process by which radiologists review ordered studies to ensure appropriateness of the diagnostic test. GE HealthCare's Intelligent Protocoling system is a scanner-integrated solution that guides users in selecting the right protocols for every imaging order thereby reducing the time spent finding the correct protocol manually from a protocoling list.

Intelligent Protocoling leverages machine learning algorithms that track, analyze, and learn from the user's behavior when choosing protocols for imaging orders at the scanner. Based on the intelligence collected, the system uses the site-specific scanner protocol library and patient clinical information in order to automate protocol selection for users, creating a seamless workflow. This helps reduce the time needed for protocol selection and ensures the proper exam is performed safely and effectively.

This white paper will review the issues associated with the current state of protocoling and detail the design and workflows of Intelligent Protocoling. This paper will also reveal early clinical evaluation evidence illustrating the performance of Intelligent Protocoling in real world clinical settings.

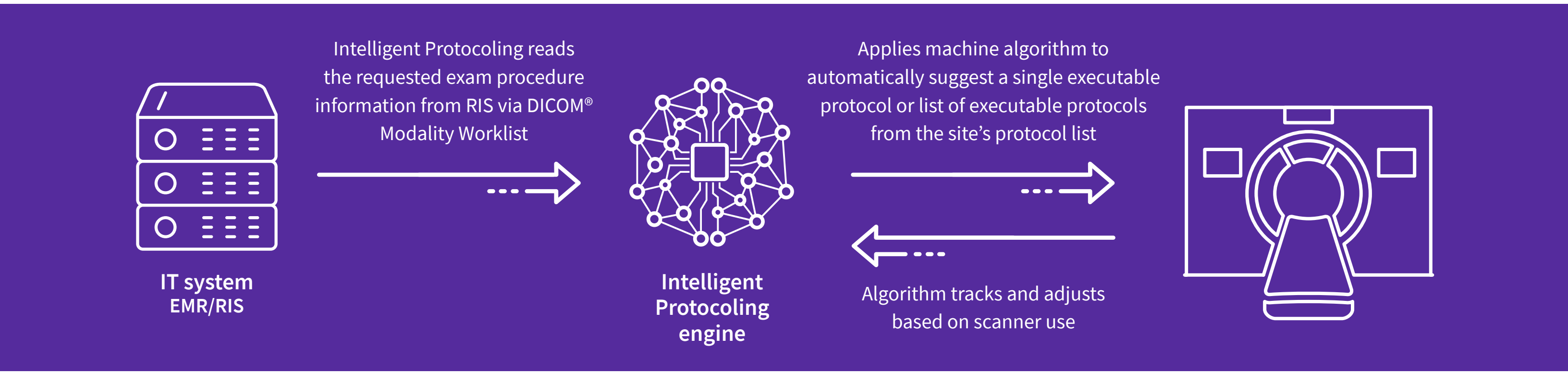


Figure 1: Intelligent Protocoling: The use of machine learning algorithms and scanner integration ensures a seamless workflow.

What is protocoling?

A CT protocol is a set of parameters that specify the exam acquisition and contrast delivery requirements in order to ensure that patient scans can be performed safely and effectively. The protocoling process utilizes the information contained in imaging orders from referring physicians. A complete imaging order will include the requested procedure, reason for exam, clinical history, and CPT codes or other billing information.

When a CT scan is requested by a referring physician, it is vetted by a radiologist. Based on the imaging order, the radiologist determines the most appropriate exam to be performed for the clinical question or patient indication. This requires detailed knowledge of the radiological appearance of pathology, the parameters of the available CT scanner, and a thorough knowledge of the types of protocols the institution performs. For example, if the referring physician requests a "CT head" for a suspected intracranial hemorrhage, the radiological protocol might be a "pre-contrast" CT head scan because CT can detect acute intracerebral blood due to the contrast between high density of blood and low density of surrounding brain. In a more complex example, if the referring physician requests a "CT abdomen" to rule out a suspected hepatocellular carcinoma, the protocol might be a "CT Liver with contrast."

Once the protocol has been determined by the radiologist, the technologist must determine which scanner protocol is most appropriate. Scanner protocols involve detailed information on the parameters needed to acquire and construct images, such as kV, mA, detector configuration, noise index, dose reduction guidance, and many other parameters.

CT protocols are often developed in-house by a team of radiologists, physicists, and technologists. They are also available from industry organizations such as the American Association of Physicists in Medicine (AAPM) and the Alliance for Radiation Safety in Pediatric Imaging, as well as academic centers like the University of Wisconsin. Regardless of how it was developed, The Joint Commission requires that protocols be standardized for clinical indication, contrast administration, patient age (e.g., pediatric or adult), size and body habitus. Protocols must also be adapted to the technical specifications of the scanner on which they will be used. Regular review and adherence to protocols is critical to optimize diagnostic quality and dose exposure.

The current state of protocoling

Protocoling is time consuming and can lead to insufficient imaging outcomes when not optimized. Protocol errors may lead to poor image quality and dose issues and result in diagnostic errors. Inconsistent imaging among studies, due to improper protocols, can also lead to repeat exams. According to a recent study, protocol errors were the most common cause of call-backs (28%) and an additional 6% of call-backs for inadequate anatomic coverage were due to incomplete protocol instructions for the technologist.[1] In addition, some 50% of abdominal CT protocols do not currently adhere to the ACR Appropriateness Criteria® concerning anatomic coverage.[2]

The clinical portion of protocoling is typically performed in a Radiology Information System (RIS). With a standalone RIS, users must manually look up the relevant patient information needed for protocoling. Access to patient information and histories is improved if the RIS is integrated with an Electronic Medical record (EMR), but protocoling still requires sizable effort on the part of the user. Protocol assignment in RIS is based on the facility's protocol dictionaries, which are often maintained manually and typically not synchronized with protocols on the scanner. Many RIS have the ability to auto-populate default protocols; however, these are overturned about 30% of the time on average.[3]

Technologists are not only responsible for performing the scan correctly, they are also at the center of the entire patient experience in the CT suite. They escort the patient into the room, position them on the table, and provide instructions and reassurance over the course of the scan. They must accommodate a wide range of patient medical conditions, patient apprehension, atypical scan situations, and, in many cases, contrast administration.

To perform the patient scan, technologists must manually select protocols on the scanner based on the requested procedure information in the modality worklist, which makes patient demographic information from the RIS available. However, there is often a wide variation in how protocols are named in scanners. In many cases, the same protocol may have different names on different scanners. In addition, since protocols assigned in the RIS may not align with those on the scanner, this can lead to an increased chance of protocol-related errors during scan acquisition.

To resolve protocol confusion and confirm appropriate exam parameters, technologists must frequently verify the protocol with a senior technologist or radiologist. This can lead to significant workflow interruptions for the technologists and the radiologists, which can slow the delivery of patient care, affect the quality of image interpretation and impact the ability to protocol, and monitor patient studies.[4] In fact, more than 50% of radiologists indicate they are interrupted at least 6 times a day with protocol-related questions and spend an average of 18 minutes a day specifically resolving protocoling issues.[5]

Protocoling challenges

1.3+ hours/day average	**6+** times/day	**$50k+** /year
Time spent on protocoling (radiology level)	Protocol-related radiologist interruptions	Overall protocoling cost
For each exam, it could take up to 2 minutes to select the correct protocol.	50% of the radiologists around the world get interrupted at least 6 times per day to answer protocoling related questions from the technologist team.	Including protocol assignment, protocol questions and potential rescan (estimate).

Table 1: Key protocoling challenges according to GE Customer Survey.[3]
Source: GE sponsored survey of 150 CT radiologists and technologists, January 2019.

The machine learning approach to protocoling

Machine learning (ML) is a subset of artificial intelligence (AI). AI is a broad term to cover the theory and development of computer systems able to perform tasks that normally require human intelligence. ML is based on the idea that systems can learn from data, patterns, and features to make decisions with minimal human intervention. Intelligent Protocoling leverages machine learning algorithms designed to track, analyze, and learn from the protocol usage behavior at the scanners to improve the protocoling process.

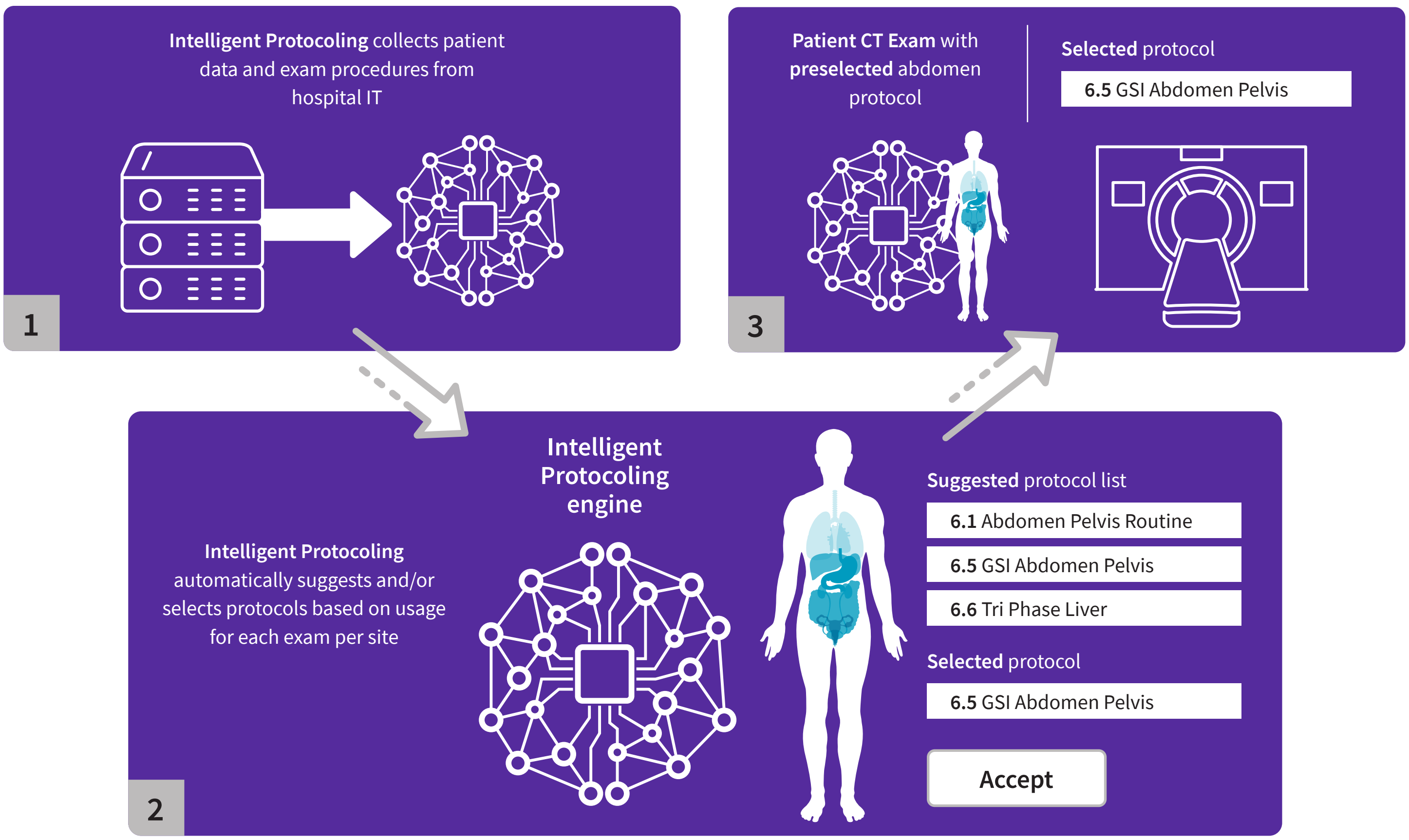


Figure 2: Using RIS data with historical selections to suggest and preselect exam protocols.

Intelligent Protocoling is a feature that helps guide users to effortlessly assign the correct scan protocol for an exam order. The Intelligent Protocoling algorithm learns from the site's protocol selection patterns for each exam procedure and accumulates protocoling intelligence over time. Based on the intelligence collected, it uses the patient clinical information in the order and the user's protocol library to automate scanner protocol selection and simplify protocol management across selected GE scanners, enterprise wide.

Intelligent Protocoling reduces the time spent searching for protocols and may help in reducing errors in protocol selection to ensure the right exam is delivered for the patient in a highly efficient manner. Elimination of suboptimal protocols can lead to standardized image quality and consistent workflow, which can help users:

- **Improve workflow efficiency:** fewer clicks, less time spent deciding the right protocol, and fewer interruptions to the radiologist
- **Reduce the cost of imaging:** time saved is money saved
- **Improve exam quality:** reduced protocoling errors and improved consistency in protocol selection across scanners and patients leads to better and more consistent exam quality

How Intelligent Protocoling works

Intelligent Protocoling reads the requested exam procedure and patient demographic information from RIS via DICOM Modality Worklist and applies machine learning to automatically suggest a single executable protocol or list of executable protocols from the site's protocol list. Intelligent Protocoling tracks and aggregates the user's actual protocol selections to continuously learn and adjust protocol recommendations based on the site's protocol selection patterns. Intelligent Protocoling aggregates protocoling across multiple scanners and can share the machine learnings across devices to be able to auto-suggest protocols faster and with a high degree of confidence.

Intelligent Protocoling works by interfacing with GE scanners to collect historical protocoling information. This information is stored locally (on each scanner) and is also aggregated at the enterprise level across scanners.* Once a preconfigured threshold based on previous selection is reached, Intelligent Protocoling uses machine learning classifiers on local and aggregated data along with demographic information for a patient to suggest appropriate protocols for an imaging exam. The scanner user interface provides a seamless way to access these suggestions and present them to the technologist right before scanning.

Key capabilities of Intelligent Protocoling include:

- Multi-site/multi scanner support across enterprise*
- RIS MWL data ingestion (vendor-agnostic)
- Auto-protocoling optimization engine per patient demographic information
- Auto-protocoling adaptive learning per protocol usage patterns
- Protocoling database (DB) exchange across devices
- Automatic protocol suggestion & selection on scanner UI

Automatic protocol suggestion and selection

Intelligent Protocoling tracks the most commonly selected protocols for the requested exam procedure from the patient worklist and displays a list of protocols in the Suggested Protocol area of the Imaging device console. The Suggested Protocols are displayed in descending order of their confidence score calculated by the protocoling machining learning algorithm. The user can select a protocol from the Suggested Protocol area and click Accept to use this protocol for a patient scan. If the user does not select a recommended protocol, the user can then manually select the desired protocol.

If the Autoselect system preference is enabled, Intelligent Protocoling automatically selects and displays a single recommended protocol in the Selected Protocols area.

For a given exam procedure, a protocol displayed in the Suggested or Selected Protocol areas will only display to the user if the number of times this protocol was previously selected by the technologist is above a predetermined threshold. Additionally, in order for a protocol to be displayed in the Selected Protocol area, its confidence score must be significantly higher than the next most commonly selected protocol. These features of the algorithm allow Intelligent Protocoling to learn based on past selections and only display Suggested and Selected Protocols with a relatively high level of confidence.

Finally, only suggested/selected protocols from adult protocols display when the adult protocol category is selected and only suggested/selected protocols from pediatric protocols display when the pediatric protocol category is selected.

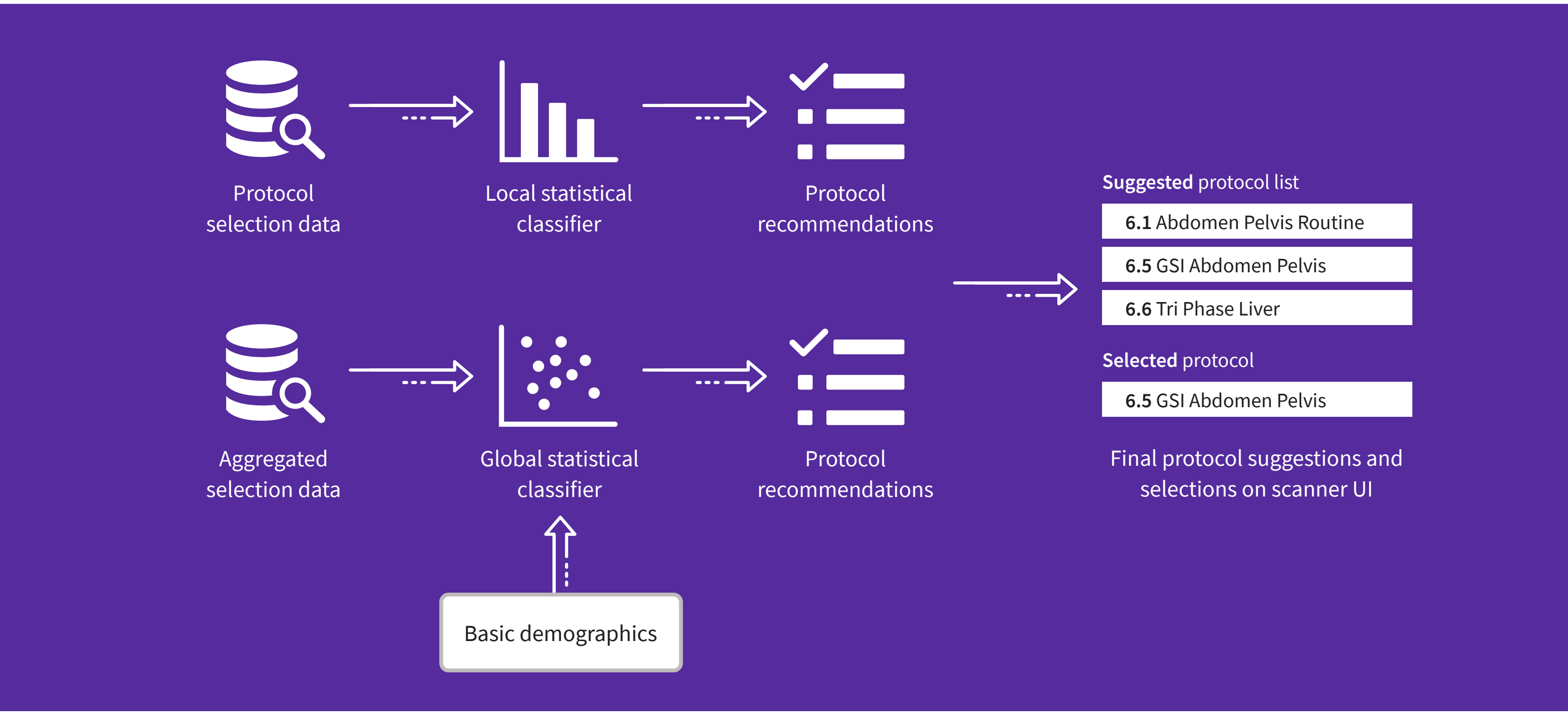


Figure 3: Machine learning applied to the protocoling process, using different sources for final protocol recommendations.

* Enterprise aggregation of protocol learnings across multiple sites/scanners requires Intelligent Protocoling on EHL. Multi-site support requires Intelligent Protocoling on EHL to be accessible through the hospital IT network from each individual scanner at each facility.

Early evidence: Clinical evaluation

The performance of Intelligent Protocoling has been evaluated at three clinical sites in the United States, Japan and France. Intelligent Protocoling was installed on the GE Revolution™ Ascend CT systems at the three sites and used as part of their standard patient care workflow. No special training was required for the technologists operating the CT scanners and using Intelligent Protocoling.

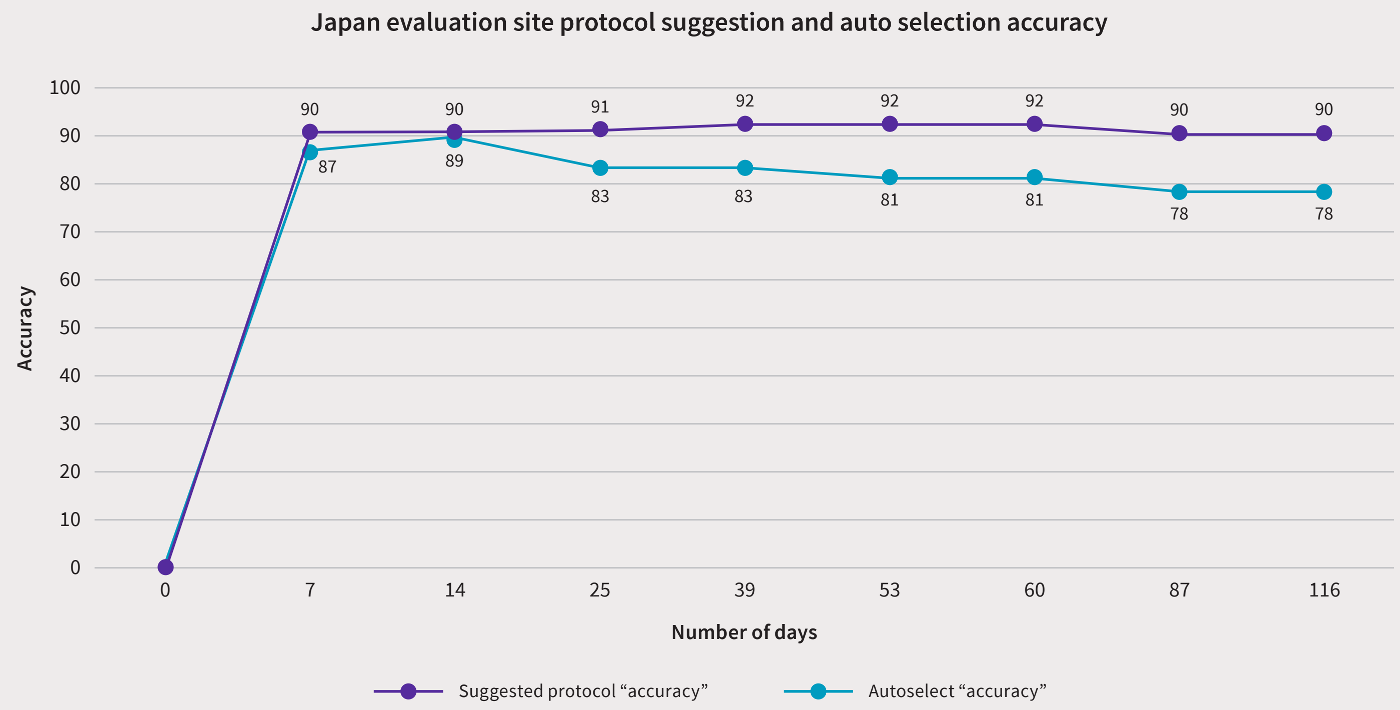
A total of 6,280 CT exam datasets were collected during a 5-month evaluation period from the clinical evaluation sites. The performance of Intelligent Protocoling was measured by the accuracy of Auto protocol suggestions and Auto protocol selection by recording the software protocol recommendations and tracking user's actions in response to these outputs into system logs.

Overall, Intelligent Protocoling demonstrated 90%+ accuracy for auto protocol suggestions across all three evaluation sites. This means users selected one of the suggested protocols in 90%+ of exams. The system has also demonstrated 74%+ accuracy for auto protocol selection from the evaluation sites. This means that in 74%+ of exams with autoselect enabled, the user selected and accepted the protocol provided by Intelligent Protocoling in the protocol auto selection area.

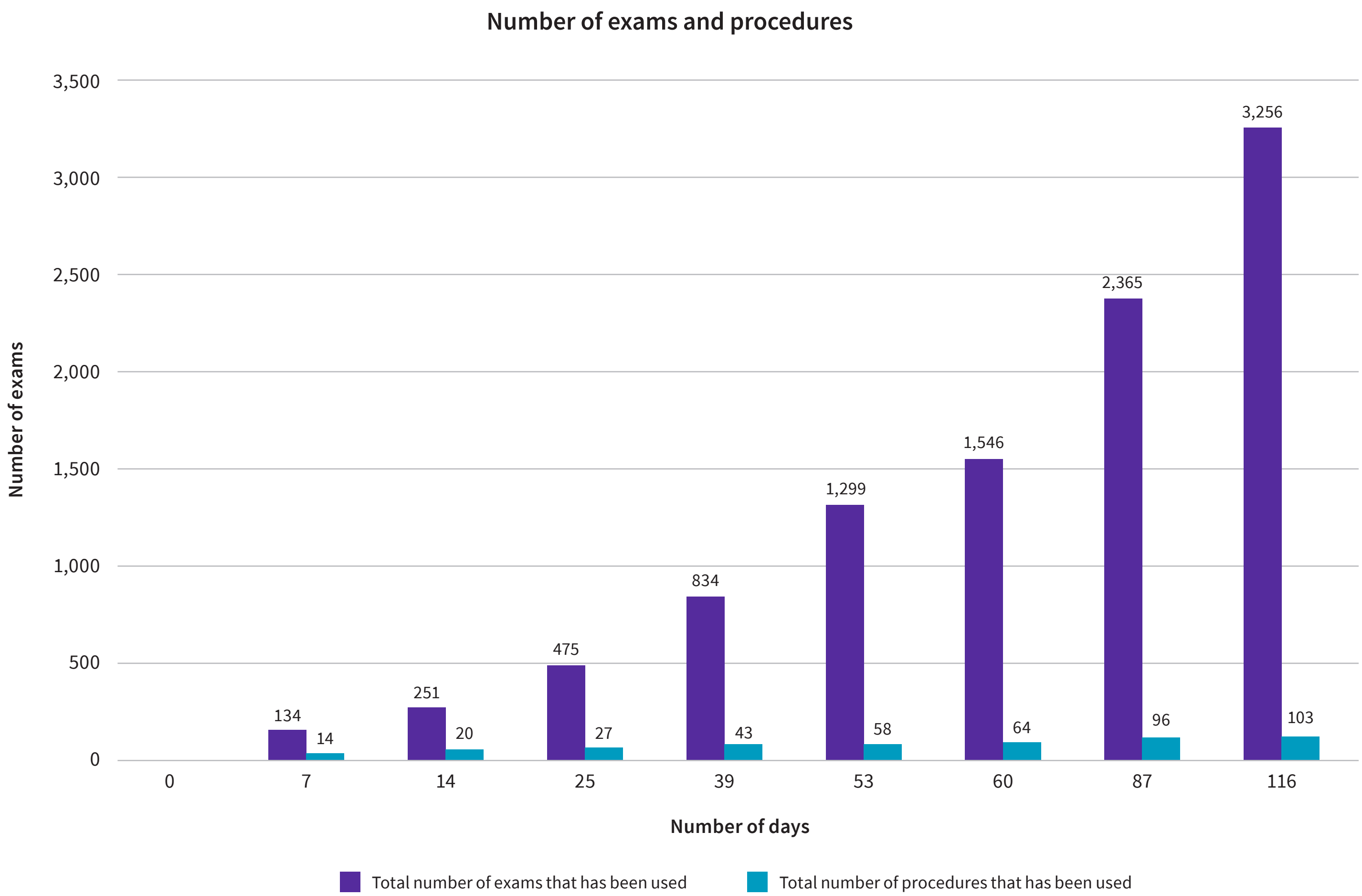
Intelligent Protocoling experience – Japan

The clinical evaluation site in Japan is a community hospital that provides high-quality medical care to patients in cooperation with local clinics and clinics. The site had 272 protocols in their system library. During the course of clinical evaluation, 3,256 exams were conducted and 101 protocols were used, which corresponds to 103 different exams descriptions.

Intelligent Protocoling made the first suggestion after tracking, analyzing and learning from the site's protocol selection patterns for 163 exams over 6 days. After 115 days of clinical runtime, the system had a protocol suggestion accuracy of 90% (2744/3028) of exams and an auto selection accuracy of 78% (1493/1906).



Graphic 1: Data of Japan Evaluation site demonstrating suggested protocol accuracy and autoselect accuracy number.

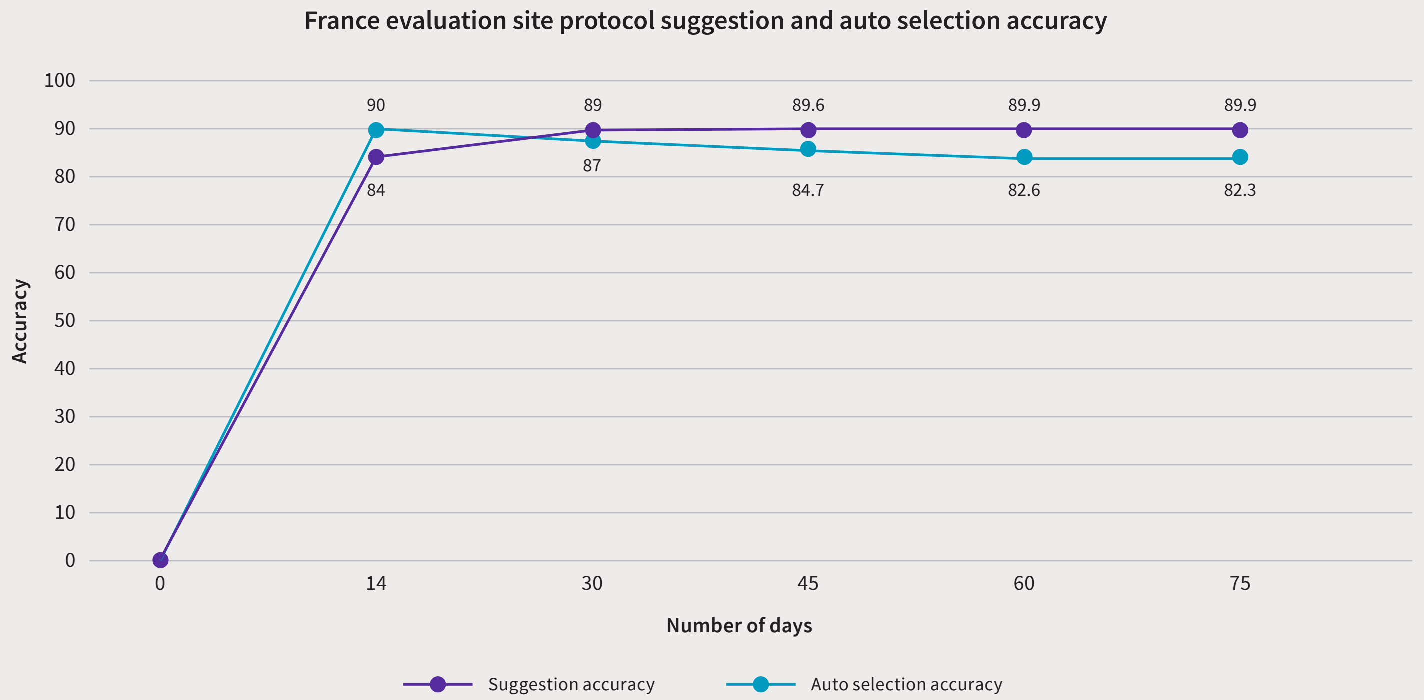


Graphic 2: Data demonstrating the number of exams and the number of procedures, demonstrating that Intelligent Protocoling streamlined the CT workflow.

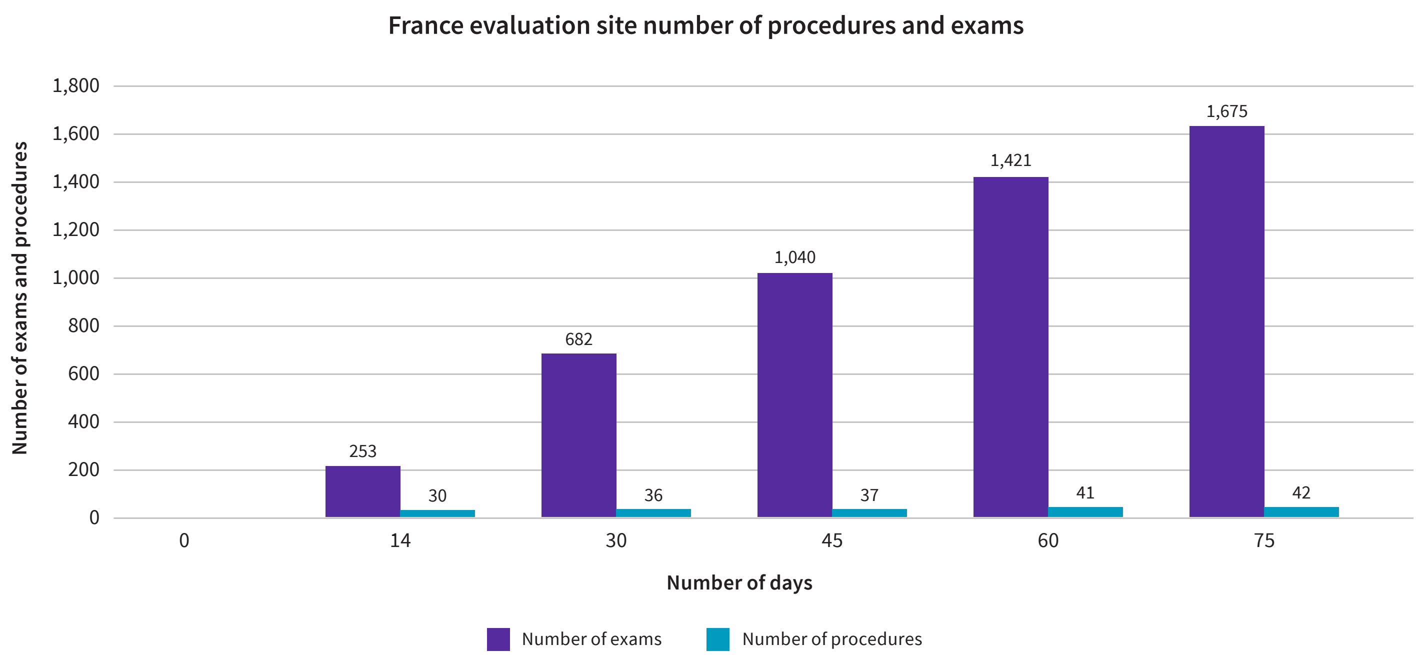
Intelligent Protocoling experience – France

The clinical evaluation site in France is a public institution which provides a full range of treatment to patients locally. The site had 318 protocols in their system library. During the course of clinical evaluation, 1,675 exams were conducted and a total of 87 protocols were used. These exams corresponded to 42 different exams descriptions.

Intelligent Protocoling made the first suggestion after analyzing and learning from 15 exams over 6 days. After 75 days of clinical runtime, the system had a protocol suggestion accuracy of 90% (1411/1675) and an auto selection accuracy of 82% (906/1100).



Graphic 3: Data of France evaluation site demonstrating suggested protocol accuracy and autoselect accuracy number.

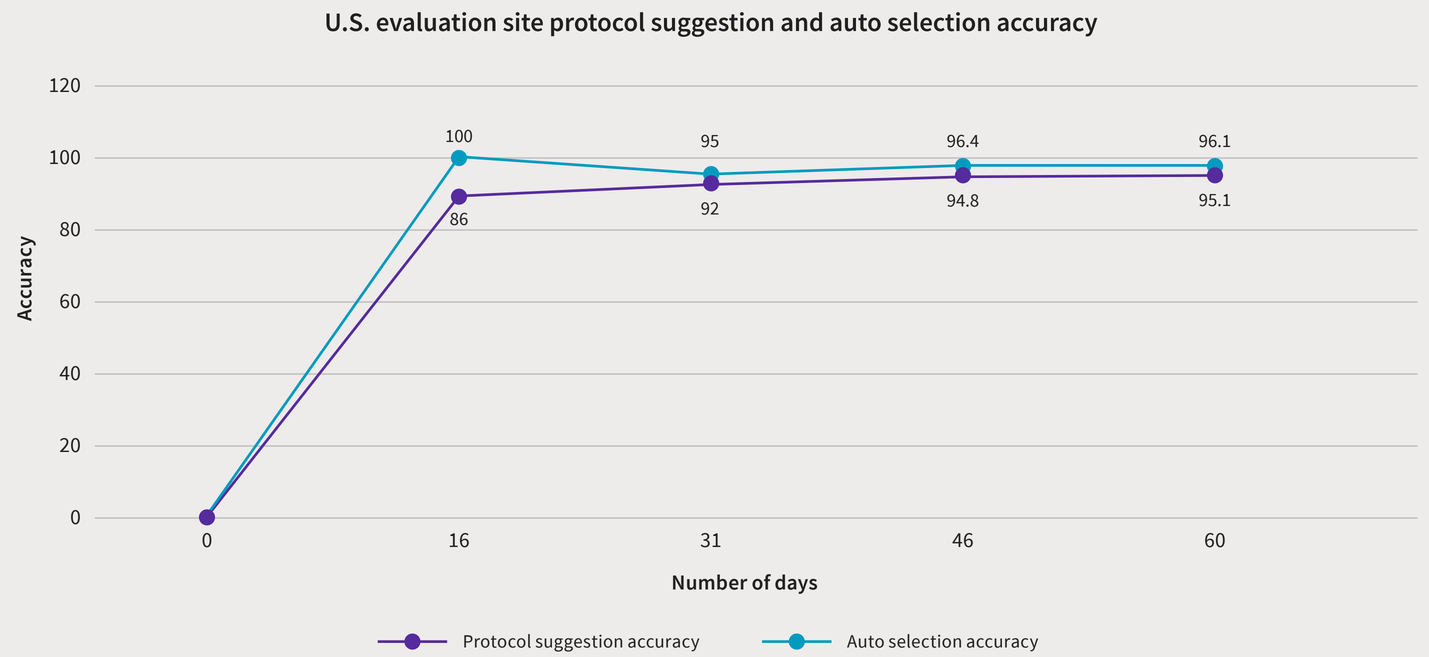


Graphic 4: Data demonstrating the number of exams and the number of procedures, demonstrating that Intelligent Protocoling streamlined the CT workflow.

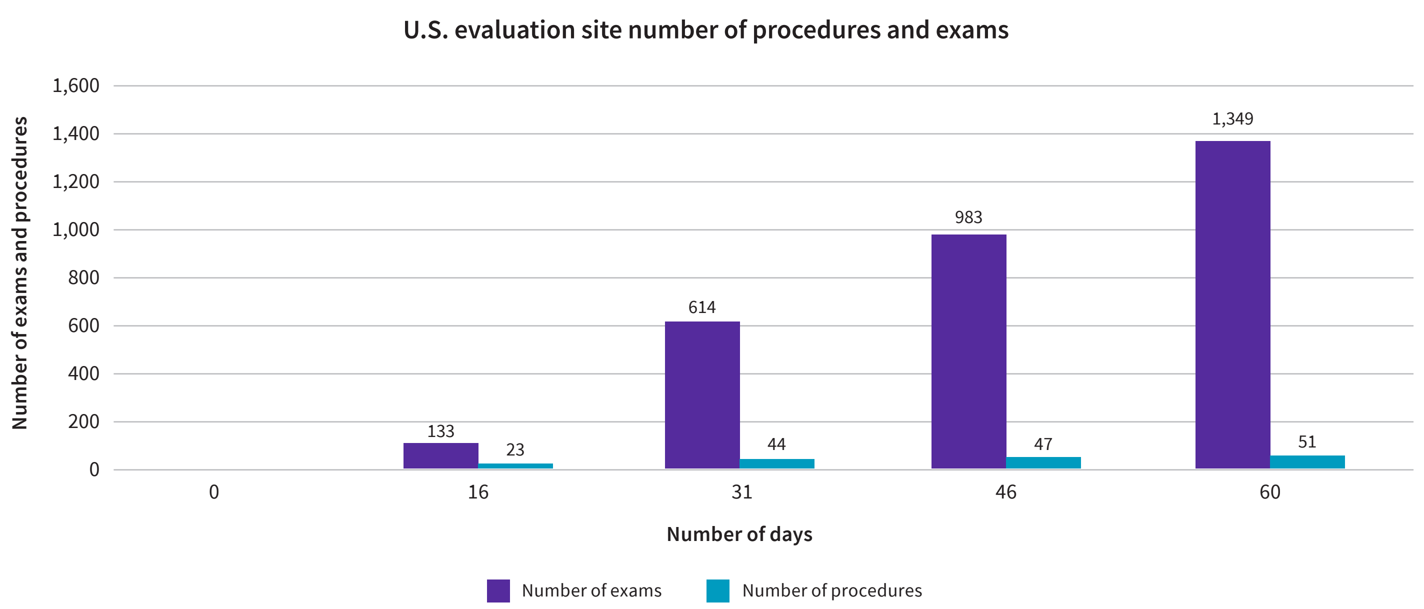
Intelligent Protocoling experience – USA

The clinical evaluation site in US is a community hospital features 133 private rooms and provides care for adult medical and surgical services, including a separate critical care unit. The Emergency Department can accommodate more than 70,000 visits annually. The site had 158 protocols in their system library. During the course of clinical evaluation, 1,349 exams were conducted and 73 protocols were used out of a total of 272 protocols. These exams corresponded to 51 different exams descriptions.

After 60 days of clinical runtime, Intelligent Protocoling had a protocol suggestion accuracy of 95% (1078/1133) of exams and an auto selection accuracy of 96% (732/761).



Graphic 5: Data of U.S. evaluation site demonstrating suggested protocol accuracy and autoselect accuracy number.



Graphic 6: Data demonstrating the number of exams and the number of procedures, demonstrating that Intelligent Protocoling streamlined the CT workflow.

Clinical and workflow improvements

Leveraging machine algorithms to automatically suggest and preselect corresponding protocols, Intelligent Protocoling streamlines the protocol selection process. Based on results of the early clinical evaluations, the system helps improve the consistency of exam quality and helps reduce time and cost of imaging.

Intelligent Protocoling user insights*

Reduce interruptions	Save time	Reduce wrong/inaccurate protocol selection	Deliver consistency
>20%	**~85%**	**42%**	**>⅔**
About half of the surveyed technologists claim that Intelligent Protocoling helped reduce interruptions to their operational workflow by greater than 20%.	Approximately 85% of the surveyed technologists agree that Intelligent Protocoling saves time in searching and selecting the right protocol.	42% of users claim that the repeat scans related to wrong or inaccurate protocol selection may be avoided using Intelligent Protocoling.	More than ⅔ of early adaptor users claim that Intelligent Protocoling helps deliver uniformity in protocol selection across patients with the same exam indication.

Table 2: Intelligent Protocoling User Insights. Based on survey responses analyzed from 32 technologists from 10 different sites using Intelligent Protocoling in their clinical practice.

**Based on survey responses analyzed from 32 technologies from 10 different sites using Intelligent Protocoling in their clinical practice. No financial incentives or conflicts exist between GE HealthCare and the survey participants.*

Conclusion

The use of machine learning promises compelling advances in the protocoling process for imaging exams. With a scanner-integrated workflow and site-specific machine learning, GE HealthCare's Intelligent Protocoling provides users with an efficient workflow tool in optimizing the protocol selection process by reducing manual steps. With 90%+ accuracy for auto protocol suggestion and 74%+ accuracy for auto protocol selection, Intelligent Protocoling guides users in selecting the right protocols for imaging orders while reducing the time spent finding the correct protocol manually from a protocoling list. This helps reduce the time radiologists and technologists need for protocol vetting and protocol selection, enabling them to spend more time on patient care and driving positive clinical outcomes.

Glossary

Artificial Intelligence (AI)

A broad term to cover the theory and development of computer systems able to perform tasks that normally require human intelligence.

Backpropagation

The central mechanism by which deep neural networks can learn. It is the messenger telling the network whether or not the network made a prediction with imperfect results. In the context of learning, backpropagation commonly uses the gradient descent optimization algorithm to adjust the weight of neurons by calculating the gradient of the loss function.

Deep learning (DL)

A subset of machine learning, DL utilizes deep neural networks which consist of layers of mathematical equations and millions of connections and parameters that get trained and strengthened based on the desired output.

Deep neural network (DNN)

An artificial neural network with multiple layers of mathematical equations and millions of connections and parameters that get trained and strengthened based on the desired output.

Inferencing

Using the trained neural network in practice. Unlike training, it doesn't include backpropagation to compute the error and update the DNN weights. It takes a network that has already been trained and uses that trained model to perform useful tasks.

Machine learning (ML)

A branch of artificial intelligence based on the idea that systems can learn from data, patterns, and features to make decisions with minimal human intervention.

References

1. Liles AL, Francis IR, Kalia V, Kim J, Davenport MS. Common Causes of Outpatient CT and MRI Callback Examinations: Opportunities for Improvement. *AJR Am J Roentgenol.* 2020 Mar;214(3):487-492. doi: 10.2214/AJR.19.21839. Epub 2019 Dec 30. PMID: 31887096.
2. Guite KM, Hinshaw JL, Ranallo FN, Lindstrom MJ, Lee FT Jr. Ionizing radiation in abdominal CT: unindicated multiphase scans are an important source of medically unnecessary exposure. *J Am Coll Radiol.* 2011 Nov;8(11):756-61. doi: 10.1016/j.jacr.2011.05.011. PMID: 22051457; PMCID: PMC4131253.
3. GE Customer Survey. Source: GE sponsored survey of 150 CT radiologists and technologists, January 2019.
4. Lee MH, Schemmel AJ, Pooler BD, Hanley T, Kennedy T, Field A, Wiegmann D, Yu JJ. Radiology Workflow Dynamics: How Workflow Patterns Impact Radiologist Perceptions of Workplace Satisfaction. *Acad Radiol.* 2017 Apr;24(4):483-487. doi: 10.1016/j.acra.2016.08.027. Epub 2016 Oct 18. PMID: 27769823.
5. GE Customer Survey. Source: GE sponsored survey of 150 CT radiologists and technologists, January 2019.

GE HealthCare

January 2024
JB28010XX