White paper

YSIO X.pree: How intelligent imaging ensures an efficient and patient-centered radiography workflow

Results of a multicenter product evaluation study

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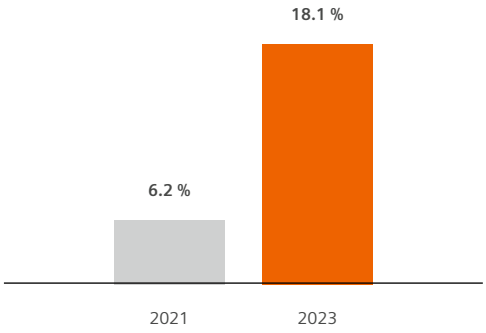
Content

Challenges in the radiography room

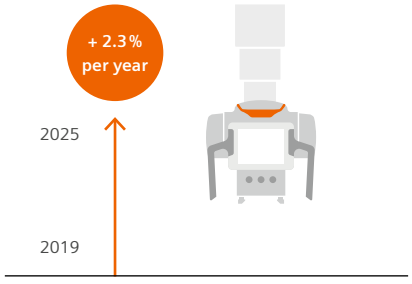
Radiology faces different challenges in the radiography room every day. Lack of time with the patient is known to be one of the biggest stressors for radiographers [1]. This is reinforced by staff shortages, heavy workloads, and a high volume of patients [2], and these factors will probably increase in the coming years.

In U.S. radiology departments, radiographer vacancy rates have grown from 6.2 percent in 2021 to 18.1 percent in 2023 [3]. In addition, a global annual increase in radiography examinations of 2.3 percent is expected between 2019 and 2025 [4]. This implies that workloads and pressures will increase for radiographers.

Radiographer vacancy rate [3]

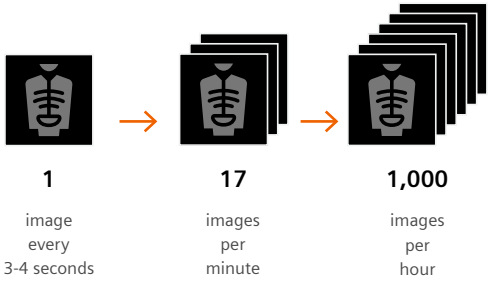


Expected increase in radiography examination volume [4]



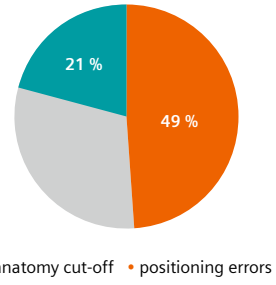
This heavy workload is not just apparent to radiographers; radiologists are also affected. At Mayo Clinic, for example, a radiologist interprets one radiological image every three to four seconds [5]. To make this challenging task as easy as possible, consistent image quality is key. One indirect measure for checking image quality in radiography departments is rejection rates. There is agreement internationally on what makes a high-quality radiographic image and when a retake is required [6].

One image every 3 - 4 seconds [5]



In a retrospective reject rate analysis of over 90,000 images, the most frequent reasons for image rejection are positioning errors (49 percent) and anatomy cut-offs (21 percent) [7]. A radiography system should help radiographers avoid these mistakes and ensure high-quality images.

Most frequent reasons for image rejection [7]

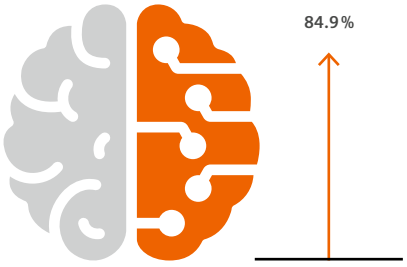


That is where system and artificial intelligence (AI) comes into play. Several intelligent imaging applications are already available: for example, to ensure that target organs are properly covered and to enhance the efficiency and pace of the acquisition process [8]. In order to fulfill their job requirements, radiographers need to be able to face and focus on their patients [9], and artificial intelligence is seen as a solution that will enable a more patient-focused workflow by addressing the increased patient throughput and the need for greater efficiency [10],[11].

In a survey of more than 1,000 radiographers, 84.9 percent believed that AI would improve radiography practice and quality assurance [12]. Another survey of radiographers analyzed the reasons for this expectation: 49.2 percent of the radiographers agreed that with the implementation of AI, radiographers could focus more on patient communication and less on technical aspects. In a different survey, benefits were seen in an increase in patient focus and in better outcomes: More than 70 percent of the radiographers agreed that AI would enhance the quality of the service they provide [13].

System and artificial intelligence may be key to tackling current and future challenges in the radiography room.

Survey of radiographers [12]
AI technology would improve radiography practice and quality assurance



YSIO X.pree features excellent user-assisting system intelligence

The YSIO X.pree radiography system has implemented system intelligence called myExam Companion, which was designed to address the challenges just described. By implementing intelligent, camera-based workflow support, the goal of myExam Companion is to standardize the quality of radiographic images and maximize patient focus while also increasing throughput.

Keeping the patient in focus

The backbone of myExam Companion is the myExam 3D Camera, which is mounted at the tube head facing in the direction of the X-ray beam (Figure 1). A live image of the camera is streamed to the workstation in the control room. This allows the radiographer to always keep the patient in focus and provide reassurance.

Figure 1:
Tube head with myExam 3D Camera

Increasing efficiency with four pioneering functionalities

The myExam 3D Camera does not just stream the live image of the patient to the workstation, it also displays the collimation field (Figure 2). This enables the following four functionalities based on system and artificial intelligence.

Figure 2:
View of myExam 3D Camera in the examination and control room

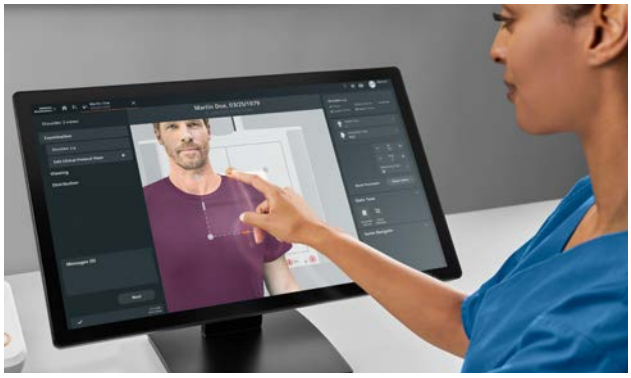


Figure 3:
Virtual Collimation on the touchscreen

1. Virtual Collimation

Virtual Collimation (VC) allows radiographers to set and/or adjust the collimation on the touchscreen in the control room (Figure 3). On the workstation, the live-streamed image of the patient is visible along an integrated display of the collimation field. The radiographer can set the collimator blades in the control room by adjusting the limits of the collimation field on the touchscreen. In other words, Virtual Collimation allows the radiographer to quickly collimate or perform adjustments at the workstation right before the exposure. This creates confidence in the radiographer and helps reduce walking time between the control and examination rooms.

Figure 4:
AI-based Auto Thorax Collimation

2. Auto Thorax Collimation

Auto Thorax Collimation (ATC) automatically sets the collimation field for thorax examinations with the help of the myExam 3D Camera and AI-based thorax detection (Figure 4). The collimation adjusts automatically based on the results of the implemented AI algorithm that detects the anatomy of the thorax, and tube and detector will align accordingly. If needed, the radiographer can adjust the collimation field manually via Virtual Collimation or using the knobs on the tube head in the examination room. In addition, the AI algorithm can be modified to meet the specific needs of each institution by setting different "site factors" for the height and width of a p.a./a.p. or lateral examination. These factors slightly reduce or increase the collimated field generated by the algorithm. This means that using Auto Thorax Collimation helps radiographers focus more on patients and their well-being while the system does the rest.

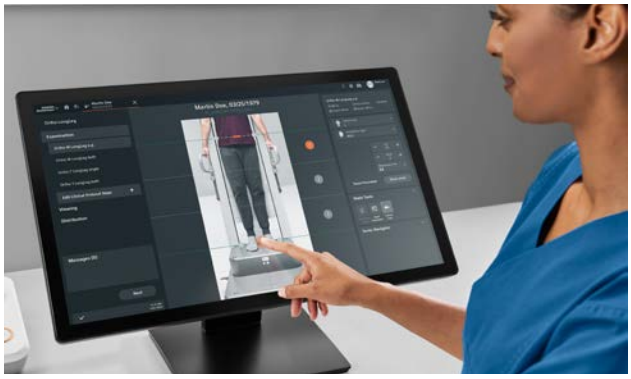


Figure 5:
Setting the limits of a long-leg examination using Smart Virtual Ortho on the touchscreen

3. Smart Virtual Ortho

Smart Virtual Ortho (SVO) supports orthopedic examinations composed of multi-image acquisitions: for example, long-leg and full-spine examinations. The integrated myExam 3D Camera enables an accurate collimation on the touchscreen in the control room for these kinds of examinations – with the patient standing in front of the Bucky Wall Stand or lying on the table. The radiographer sets the limits of the collimation on the touchscreen and the system gives direct visual feedback on the division into sub-images (Figure 5). This helps speed up the workflow and supports the radiographer in deciding if an exam with fewer images is possible. After an automatic acquisition of up to four images with tilting of the tube, the system automatically composes the acquired images into a single full-length image.

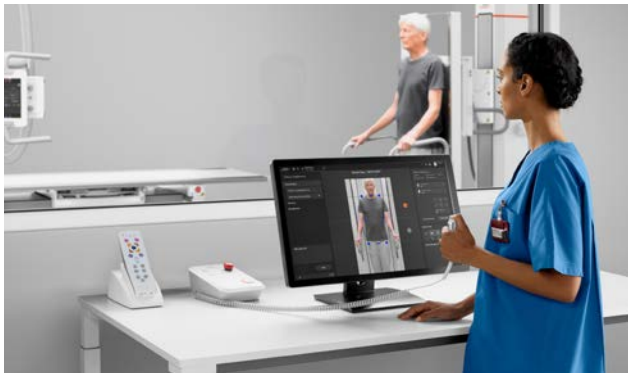


Figure 6:
Automated workflow with Auto Long-Leg & Full-Spine Collimation

4. Auto Long-Leg/Full-Spine Collimation

Auto Long-Leg/Full-Spine Collimation even enables automated collimation for orthopedic examinations in front of the Bucky Wall Stand (Figure 6). With the help of the myExam 3D Camera and AI-based anatomy detection of the whole leg or the full spine, the feature automatically sets the collimation field and the division into sub-images. If needed, the radiographer can adjust the collimation field manually via Smart Virtual Ortho on the touchscreen in the control room. As in the case of Auto Thorax Collimation, specific institutional preferences can be accommodated by modifying the site factors for the height and width of the collimation field.

Multicenter product evaluation study

The novel functionalities of YSIO X.pree offer the opportunity to improve the radiography workflow by minimizing system interactions – with the goal of speeding up examinations and allowing radiographers to focus more on the patient. To determine if this is true in the real-world routine at medical facilities, a multicenter product evaluation study was performed. Different hypotheses with a focus on workflow efficiency were tested in the clinical routine at five institutions in Europe and the U.S. between October 2022 and March 2023.

- **Diagnostikum Linz** in Austria: one location of an Austria-wide group of diagnostic centers
- **Klinikum Forchheim** in Germany: a general and academic teaching hospital
- **Johannes Wesling Klinikum Minden** in Germany: a university hospital providing maximum care
- **Venlo location of VieCuri Medisch Centrum** in the Netherlands: a medical center and academic teaching hospital
- **Ohio State Outpatient Care Dublin** in the U.S.: one location of the Ohio State University Wexner Medical Center

Two researchers conducted structured observations during regular radiography examinations to count specific system interactions and to record the time stamps of different tasks during a radiographic examination. One observer was in the examination room and the other in the control room. One segment of the observed examinations was conducted with the Virtual Collimation, Auto Thorax Collimation, and Smart Virtual Ortho functionalities activated, and the other with the features deactivated by switching off the myExam3D Camera.

In addition to the observations, a structured interview was conducted with at least two radiographers per institution to collect their subjective evaluation of the features of myExam Companion. For Auto Thorax Collimation, an evaluation of the collimation per image by one or two radiologists per site was also recorded. If the automatic collimation for the thorax exposure was manually corrected, the system log data was analyzed to find out how the collimation was changed. An overview of the applied research methods and the number of included data sets are listed in Table 1.

Research methods	Virtual Collimation (VC)	Auto Thorax Collimation (ATC)	Smart Virtual Ortho (SVO)
Structured observations	294 VC on 154 VC off 140	251 ATC on 139 ATC off 112	82 SVO on 39 SVO off 43
Radiographer interviews	14	14	14
Radiologist interviews	-	9	-
System log data	-	251 ATC on 139 ATC off 112	-

Table 1:
Research methods and number of included data sets

Confidence and efficiency using Virtual Collimation

Virtual Collimation was designed to instill confidence in the radiographer and reduce walking time between the control and examination rooms for a more efficient radiography workflow.

The structured interviews revealed that Virtual Collimation helped 100 percent of the users to detect whether a patient had moved or was still correctly positioned (Figure 7). The radiographers explained that this reassurance is very important for unstable patients. In addition, it was mentioned that the camera allowed for an easier and more ergonomic view of the patient in certain room layouts. For example, in one room radiographers had to bend their body to see the patient through the window of the control room. This shows that Virtual Collimation improves workplace ergonomics and creates confidence in radiographers, because they can easily confirm if the acquisition can be performed correctly just before exposure.

Virtual Collimation helped 100 percent of radiographers detect whether patients had moved or were still positioned correctly before image acquisition.

Virtual Collimation supports correct positioning

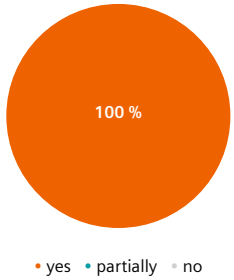


Figure 7:
Answers from 12 radiographers to the question, "Does VC help you detect whether the patient has moved/is still correctly positioned?"

Virtual Collimation not only creates confidence, the option to adjust the collimation in the control room just before image exposure can also speed up the workflow of radiographers. 57 percent of the radiographers agreed that they saved time in their radiography workflow (Figure 8). Radiographers said that this was because Virtual Collimation offers the ability to determine whether the patient has moved before the acquisition and if the field of view needs to be modified. Otherwise, they would need to walk back into the examination room to adjust the collimation using the knobs on the tube head.

The observations at the different sites revealed another way to save time using Virtual Collimation. If two people worked on the same system, the workflow was more efficient due to conducting the work steps simultaneously: One person positioned the patient in the examination room and the other person collimated on the touchscreen in the control room.

The reassurance that Virtual Collimation offers the user was also apparent during the observations: In 71 percent of the examinations, Virtual Collimation was used to check the field of view or to adjust the collimation on the touchscreen (Figure 9). In the cases where collimation was modified on the touchscreen, it also saved the time needed to walk back into the examination room to perform this step using the knobs on the tube head.

Virtual Collimation was used in 71 percent of all examinations to check the field of view or to adjust it at the workstation.

Both the interviews and the observations indicated that Virtual Collimation created confidence as well as several time-saving opportunities for the users, ensuring a more efficient workflow.

Virtual Collimation saves time

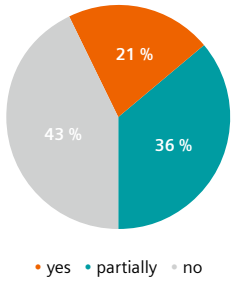


Figure 8:
Answers from 14 radiographers to the question, "In your opinion, is VC saving you time during your workflow?"

Use of Virtual Collimation

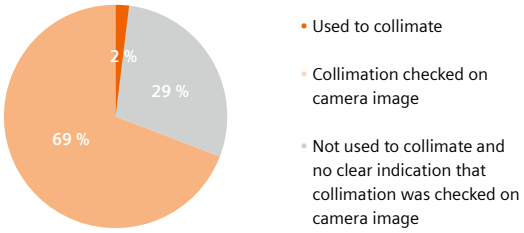


Figure 9:
Observed use of VC in 292 X-ray exposures

Fast and efficient workflow using Auto Thorax Collimation

The AI-based Auto Thorax Collimation was designed to take over any required manual interactions from the radiographer and to speed up the examination workflow.

During the observed examinations, the radiographers kept the results of the Auto Thorax Collimation in 78 percent of the cases without adjusting the collimation field. In only 22 percent of the examinations (30 of 139 observed exposures), they manually modified the result of the algorithm. Figure 10 shows the manual adjustments for each institution. While three sites rarely modified the collimation, two institutions adjusted the field of view in 36 percent and 57 percent of the exposures respectively.

In terms of the height of the collimation field, most of the modified cases were adjusted between -2 cm and + 2 cm and for the width between -4 cm and 4 cm (Figure 11). The working mode of Auto Thorax Collimation obviously differs among institutions, and it could develop its full potential when established in the clinical routine.

Quality is an important factor in the acceptance of an automated functionality. In the case of collimation, it should have the same quality as manual collimation performed by a well-educated radiographer. Table 2 shows the median judgment of the nine radiologists of the collimation in the examinations observed at their respective institutions: For the majority of the readers, the median value for "ATC on" and "ATC off" was the same, and for only two readers did the median value slightly differ. This indicates that the automatically collimated images were accepted by the radiologists at a similar rate as the manually collimated images. This finding opens the door for further research to analyze the radiologists' acceptance and its dependency of the radiographers' level of experience and the settings for different site factors in more detail.

Number of examinations with Auto Thorax Collimation and number of manual adjustments

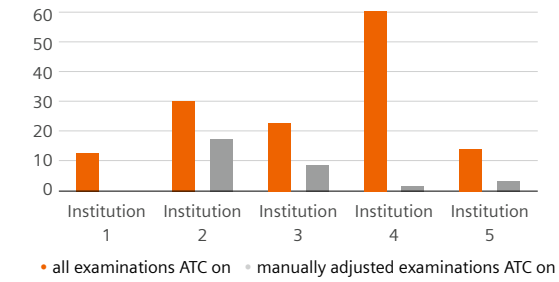


Figure 10:
Analysis of the manual adjustments to ATC in the observed examinations by institution via the system log data

Deviation of manual adjustment of Auto Thorax Collimation

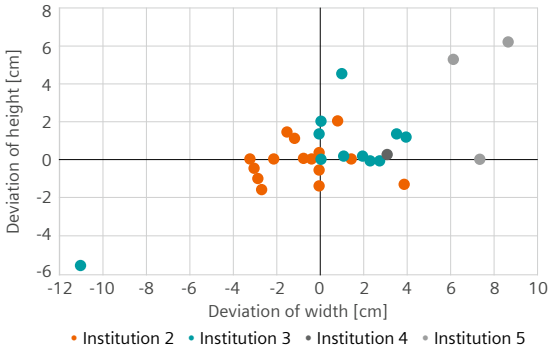


Figure 11:
Analysis of deviation in 30 manual adjustments to ATC

Reader (number of exams evaluated)	Median collimation judgement	
	ATC on	ATC off
Reader 1 (19)	5	5
Reader 2 (21)	3.5	4
Reader 3 (59)	5	5
Reader 4 (59)	5	5
Reader 5 (40)	3	3
Reader 6 (40)	4	4
Reader 7 (19)	2	2
Reader 8 (86)	4	4
Reader 9 (86)	4	5

Table 2:
Median judgement of radiologists on the question, "How do you judge the collimation of the following images according to your criteria from 1 = insufficient to 5 = very good?" Each radiologist rated the images that were acquired at the own institution.

Another aspect of Auto Thorax Collimation is the potential to standardize collimation across different radiographers in a radiology department. 77 percent of the radiographers interviewed think that the collimation fields are more similar among different colleagues with Auto Thorax Collimation than without it (Figure 12). Therefore, the feature offers an opportunity to achieve a consistent collimation across different colleagues in a radiology department.

The automated collimation for chest examinations enables fewer system interactions, which was confirmed during the observations: Average system interactions prior to the image acquisition were reduced from 2.26 to 0.99 – in other words, by 56 percent, mainly because fewer manual interactions with the collimator blades were needed (Figure 13). A difference in system interactions between both "ATC on" and "ATC off" groups was confirmed by a non-parametric Wilcoxon-Mann-Whitney test on all exposures, and it was also separately calculated for p.a. and lateral (all: $p < 0.0001$, p.a.: $p < 0.0001$, lat: $p < 0.0001$). Fewer system interactions by the user means more time for other activities, including focusing on interacting with the patient. 36 percent of the radiographers interviewed confirmed that they had more attention on the patient working with Auto Thorax Collimation than without the feature.

Auto Thorax Collimation reduced system interactions during chest X-rays prior to image acquisition by 56 percent.

Collimation similarity of chest X-rays across different radiographers with Auto Thorax Collimation

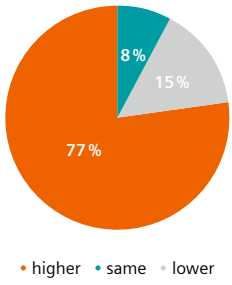


Figure 12:
Answers from 13 radiographers to the question about how the collimation varies across different radiographers with "ATC on" compared with "ATC off"

Average system interactions thorax scan

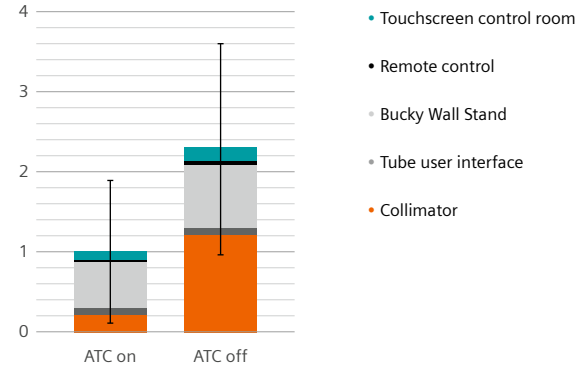


Figure 13:
Average observed system interactions of 221 chest X-rays with and without ATC

The automated workflow does not just reduce manual system interactions, it also results in a faster chest X-ray examination. The exam duration – from the moment when positioning the patient starts at the Bucky Wall Stand until the image appears on the workstation – was 28 percent shorter with Auto Thorax Collimation, as shown in Figure 14. The mean for the exam duration was 33 seconds with and 46 seconds without Auto Thorax Collimation. The benefit was even higher for p.a. (33 seconds vs. 47 seconds) than for lateral examinations (34 seconds vs. 45 seconds) (Figure 15), and the difference in exam duration between both groups ("ATC on" and "ATC off") was confirmed by a non-parametric Wilcoxon-Mann-Whitney test on all exposures. It was also calculated separately for p.a. and lateral (all: $p < 0.0001$, p.a.: $p < 0.0001$, lat: $p < 0.0001$). These results strongly indicate that Auto Thorax Collimation enables a shorter scan duration.

Exam duration of chest X-rays

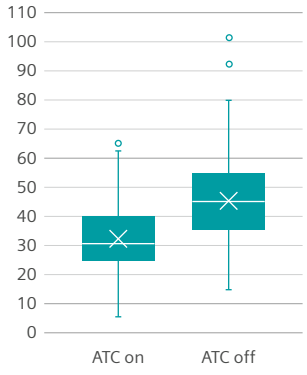


Figure 14:
Box plot showing exam duration of 189 chest X-rays (95 ATC on, 94 ATC off)

Exam duration of chest X-rays

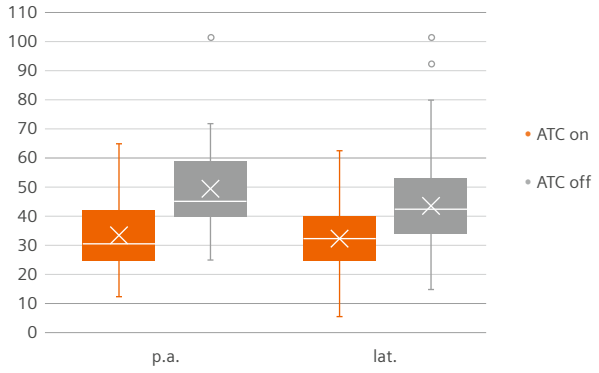


Figure 15:
Box plot showing exam duration of 95 p.a. (47 ATC on, 48 ATC off) and 94 lateral (48 ATC on, 46 ATC off) chest X-rays

Chest X-ray exam duration was 28 percent shorter with Auto Thorax Collimation than with manual collimation.

Using Auto Thorax Collimation results in fewer manual machine interactions and shorter examinations while still providing high-quality images. This ensures a faster and more efficient chest X-ray workflow.

Easy and reliable long-leg and full-spine examinations using Smart Virtual Ortho

Long-leg and full-spine examinations are composed of several single exposures, as described above. Smart Virtual Ortho was designed to enable an easy and reliable preparation workflow for these exposures.

90 percent of the radiographers interviewed confirmed that setting the field of view for this kind of orthopedic examination is easier with Smart Virtual Ortho than with a conventional tilting technique used on the tube in the examination room (Figure 16). Smart Virtual Ortho does not just offer a comfortable workflow: 36 percent of the users stated that the feature helps prevent mistakes (Figure 17) and that the expected retake rate is 46 percent lower (Figure 18). In addition, 55 percent of the radiographers said that they put less attention on the system and focused more on the patient. This indicates that Smart Virtual Ortho can enable an easy and reliable patient-centered workflow for long-leg and full-spine examinations.

Setting the ortho range with Smart Virtual is ...

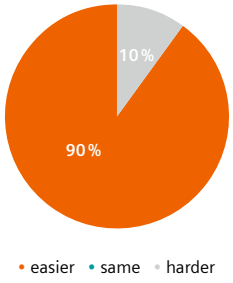


Figure 16:
Answers from 10 radiographers to the question, "Using SVO, what would you say: Setting the ortho range is easier, the same, or harder than setting the range without the camera-based feature?"

Setting the ortho range with Smart Virtual Ortho leads to ...

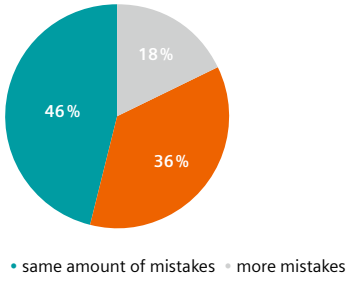


Figure 17:
Answers from 11 radiographers to the question, "Using SVO, what would you say: Setting the ortho range leads to less, the same amount, or more mistakes?"

Expected retake rate

Figure 18:
Expected retake rate with and without SVO (calculated average from 11 radiographers' responses)

Smart Virtual Ortho does not just help bring the patient into focus, it also creates a more efficient examination workflow. It reduced the scan duration by 31 percent for long-leg and full-spine examinations: The mean scan duration was 67 seconds using Smart Virtual Ortho and 97 seconds without it (Figure 19). The time needed to set the ortho range – in other words, the time between setting the upper and the lower limits of the collimation field – was 7 seconds with and 19 seconds without Smart Virtual Ortho, resulting in a time reduction of 63 percent (Figure 20). The difference in scan duration and the time needed to set the ortho range between both groups "SVO on" and "SVO off" was confirmed by a non-parametric Wilcoxon-Mann-Whitney test (scan duration: $p < 0.0001$; setting the ortho range: $p < 0.0001$). In addition, the spread of the time needed to set the ortho range was much higher for "SVO off" than "SVO on" as shown in Figure 20, which indicates a more standardized workflow using Smart Virtual Ortho.

These results indicate that Smart Virtual Ortho helps radiographers perform this special type of orthopedic examination composed of several single exposures. Smart Virtual Ortho enables an efficient and standardized as well as easy and reliable workflow for long-leg and full-spine examinations.

Scan duration of ortho examinations

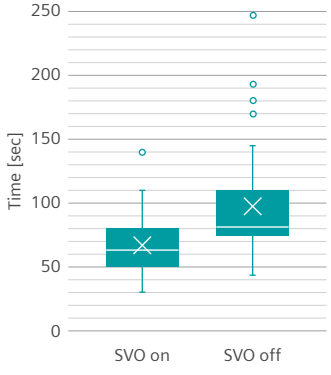


Figure 19:
Box plot for scan duration of 74 ortho examinations

Time needed to set the ortho range

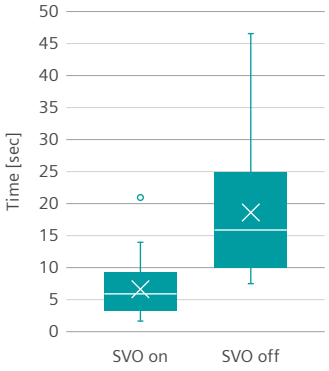


Figure 20:
Box plot for time needed to set the ortho range of 82 examinations

For long-leg and full spine examinations, Smart Virtual Ortho was able to speed up range adjustments by 63 percent and the scan duration by 31 percent.

Auto Long-Leg/Full-Spine Collimation for even faster and easier orthopedic examinations

The function "Auto Long-Leg/Full-Spine Collimation" came on board in the current version of YSIO X.pree, but it was not included in the multicenter product evaluation study. Similar to the Auto Thorax Collimation feature, the entire collimation workflow for long-leg and full-spine examinations is automated by an AI-based algorithm that detects the anatomy of the whole leg or the full spine. This leads to an even faster and easier workflow for composed orthopedic examinations.

The feature automatically sets the ortho range – in other words, the upper and lower limits of the collimation field – so that no system interaction is necessary for this workflow step. Assuming a perception time of 1.5 seconds to judge the results of the automated collimation [14], and comparing this time with the average observed 7 seconds to set the ortho range using Smart Virtual Ortho in the multicenter product evaluation study – radiographers can potentially speed up their range adjustments in long-leg and full-spine examinations by 79 percent compared to Smart Virtual Ortho.

Auto Long-Leg/Full-Spine Collimation can potentially speed up range adjustments in long-leg and full-spine examinations by 79 percent compared with Smart Virtual Ortho.

Summary and outlook

Great potential has been seen in system and artificial intelligence for tackling current and future challenges in radiography: However, little was known about how they would change the quality, efficiency, and cost of healthcare [15]. The current multicenter product evaluation study describes a real-world validation of the myExam Companion system intelligence features in YSIO X.pree:

- Virtual Collimation gave radiographers greater confidence in performing their tasks and created opportunities for saving time.
- Auto Thorax Collimation was able to speed up the chest X-ray examination workflow by requiring fewer manual interactions to maintain collimation quality.
- Smart Virtual Ortho enabled an easy, efficient, and more standardized workflow with fewer manual interactions during long-leg and full-spine examinations.

These results show that the novel assistance functions in YSIO X.pree with myExam Companion precisely address the challenges of higher workloads and fewer staff in the radiography room.

The integration of intelligence into radiography systems has just begun and will continue to develop. By adding the new feature “Auto Long-Leg/Full-Spine Collimation” to its system intelligence with my Exam Companion, YSIO X.pree opens the door for more research activities to demonstrate the benefits of system intelligence in the radiography department.

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Abreviations

AI	Artificial Intelligence
ATC	Auto Thorax Collimation
SVO	Smart Virtual Ortho
VC	Virtual Collimation

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