Utilizing Artificial Intelligence-Assisted Heuristic Scanning to Enhance the Efficiency of Urine Cytology Slides Scanning

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Introduction

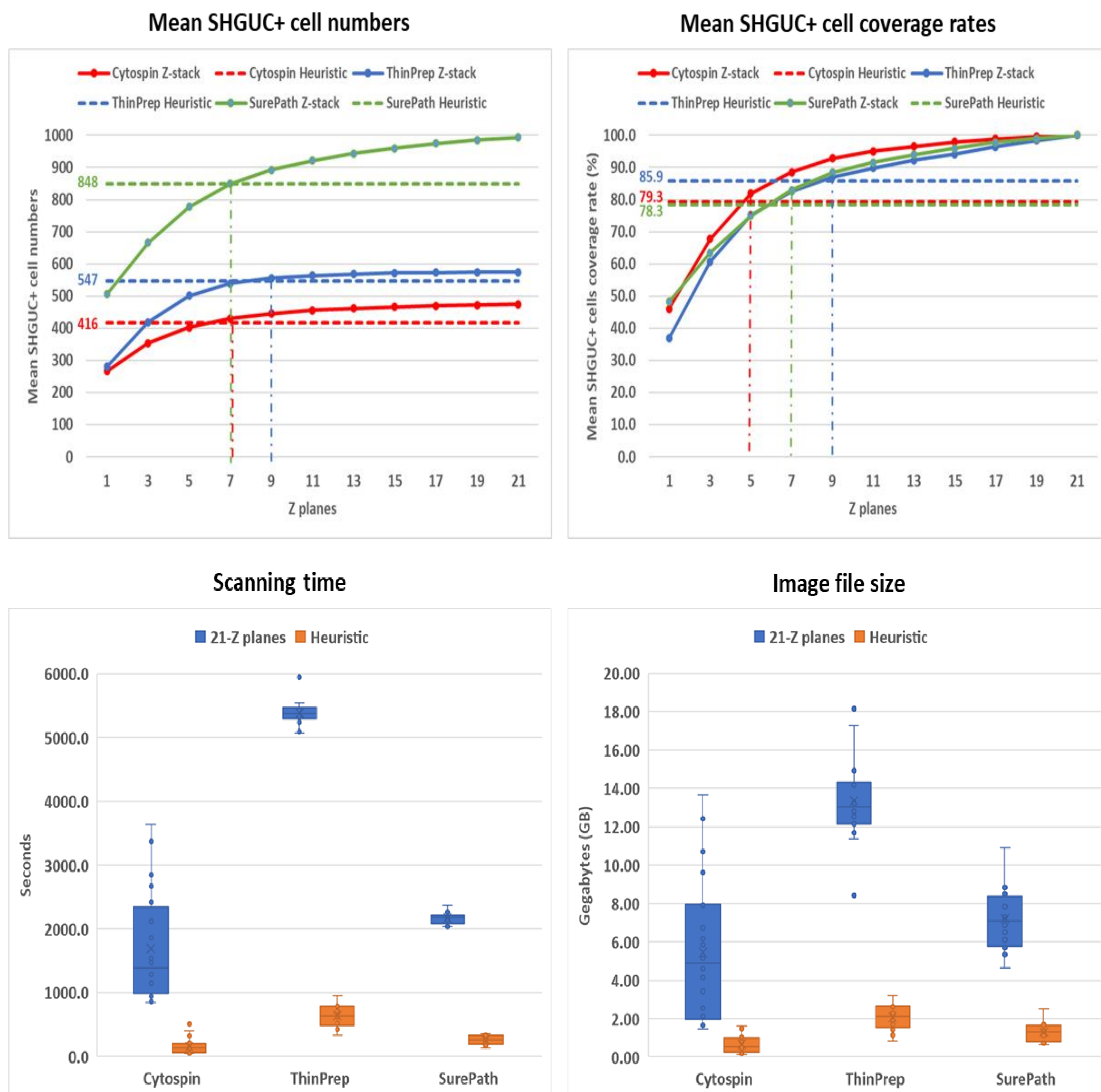
- Acquiring well-focused whole-slide images (WSI) is challenged in digital cytology due to the 3D and uneven cell distribution.
- Z-stack scanning is the primary solution but has limitations such as extended scanning time, image file size and review process.
- This study aims to evaluate a new artificial intelligence (AI)-assisted technology, heuristic scanning, to overcome these challenges.
- Unlike Z-stack scanning that captures multiple planes across the entire slide, heuristic scanning uses an AI algorithm to identify potential cancerous areas and their optimal focus planes.

Materials and Methods

- Z-stack and heuristic scans were implemented on 52 urine cytology slides from bladder cancer patients, including various slide types.
- The Leica Aperio AT2 scanner was used for Z-stacking, scanning 21 Z-planes.
- An AI algorithm analyzed each Z-plane for suspicious/cancer cell (SHGUC+), with evaluations from a single plane to all 21 planes.
- Heuristic scanning results were produced using in-house software analyzing the scanner's WSIs across 21 Z-planes.
- Scanning performance was assessed using metrics like SHGUC+ numbers, coverage rate, scanning time, image file size, and interpretation accuracy for slides with few SHGUC+ cells.

Results

Figure 1. Cost-effectiveness analysis of 21-Z planes and heuristic scanning



- Performance of heuristic scanning was like Z-stack scanning, as reflected in the comparable average SHGUC+ cell numbers and coverage rates: 416 cells/79.3% versus 431 cells/81.9% in 5 planes of Cytospin; 547 cells/85.9% versus 556 cells/87.1% in 9 planes of ThinPrep; 848 cells/78.3% versus 850/82.9% in 7 planes of SurePath (Figure 1, upper panels).

Table 1. The AI-aided interpretations for WSIs with few SHGUC+ cells

Preparation	Scan modality					Four categories interpretation			
	The optimal focal plane		Heuristic		21 Z-planes	Original diagnosis	The AI-aided interpretation*		
	Cells	Coverage rate	Cells	Coverage rate	Cells		The optimal focal plane	Heuristic	21 Z-planes
Cytospin	16	45.7%	26	74.3%	35	HGUC	HGUC	HGUC	HGUC
	6	37.5%	10	62.5%	16	HGUC	SHGUC	SHGUC	HGUC
	11	57.9%	15	78.9%	19	HGUC	HGUC	HGUC	HGUC
	5	38.5%	10	76.9%	13	SHGUC	AUC	SHGUC	HGUC
	3	21.4%	11	78.6%	14	HGUC	AUC	HGUC	HGUC
	23	49.6%	40	81.6%	49	HGUC	HGUC	HGUC	HGUC
ThinPrep	0	0.0%	9	50.0%	18	HGUC	NHGUC	SHGUC	HGUC
	4	40.0%	7	70.0%	10	HGUC	AUC	SHGUC	SHGUC

*By the TPS 2.0 guidelines. HGUC: >10 SHGUC+ cells; SHGUC: 6-10 SHGUC+ cells; AUC: 2-5 SHGUC+ cells; NHGUC: 0-1 SHGUC+ cell

- When compared to Z-stack scanning, heuristic scanning notably reduced both scanning times (from 1693.0 to 159.3 sec in Cytospin, 5385.1 to 640.4 sec in ThinPrep, and 2170.8 to 257.4 sec in SurePath) and image file sizes (from 5.44 to 0.66 GB in Cytospin, 13.35 to 2.05 GB in ThinPrep, and 7.21 to 1.30 GB in SurePath) (Figure 1, lower panels).
- The Leica scanner produced eight WSIs with low SHGUC+ cell numbers, comprising six Cytospin and two ThinPrep slides (Table 1).
- Using the TPS 2.0 guidelines for the category interpretation, the optimal focal plane scanning correctly categorized three of the eight slides (37.5%). In contrast, heuristic scanning accurately categorized five out of the eight slides (62.5%).

Conclusion

- Heuristic scanning provides an effective alternative to conventional Z-stack scanning for digital cytology by identifying a similar number of SHGUC+ cells with a significant reduction in scanning time and image file size.
- WSIs created by heuristic scanning reduced AI-aided category interpretation inaccuracies in digital urine cytopathology compared with optimal Z-plane WSIs.

Assessing the Practicability of Artificial Intelligence-Assisted Digital Urine Cytology in Diagnosing Bladder Cancer in Clinical Practice

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Introduction

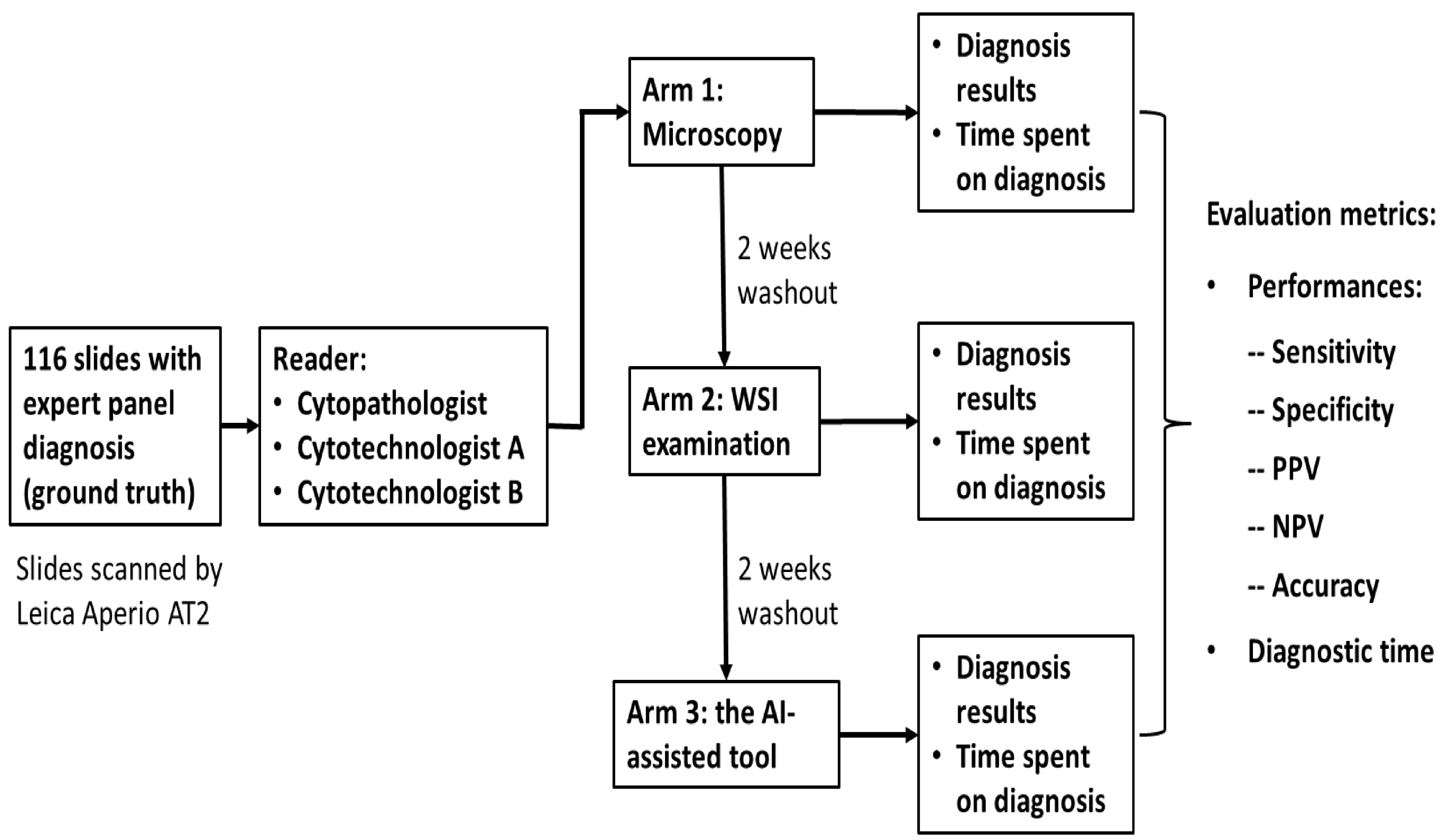
- The use of urine cytology for diagnosing bladder cancer in clinical practice is constrained by the requirement for experienced cytologists and the time-consuming diagnostic process.
- Recent advancements in digital cytopathology and artificial intelligence (AI) offer solutions to those challenges.
- We developed a novel deep-learning-based tool tailored to detect atypical urothelial cells in whole-slide images (WSIs) for improving bladder cancer diagnosis.
- We evaluated if this AI-assisted tool could reduce reading time while maintaining diagnostic performance comparable to microscopy.

Materials and Methods

- 116 urine cytology slides from hospital patients were scanned into WSIs using the Leica Aperio AT2 scanner.
- This clinical study used three diagnostic methods: Microscopy, WSI examination, and an AI-assisted tool that showcased the 24 most suspicious atypical cell images in a gallery for each WSI (Figure 1).
- Diagnostic results from all readers using the three methods were compared against an expert panel consensus which served as the ground truth (30 positive and 86 negative cases).
- Performance metrics of each method were assessed, and the time spent on each slide, both in total and on average, were documented.

Results

Figure 1. The study design and flowchart



- When compared to Microscopy, the AI-assisted tool increased sensitivity (76.7-93.3% vs. 83.3-100.0%) and negative predictive value (NPV) (92.0-96.8% vs. 94.3-100.0%) but decreased specificity (70.9-96.5% vs. 54.7-96.5%), positive predictive value (PPV) (52.8-88.5% vs. 43.5-89.3%) and accuracy (76.7-91.4% vs. 66.4-93.1%) (Table 1).
- Microscopy and WSI examination exhibited comparable overall performance. However, distinct variations in results were noted among the three readers across the methods.
- When comparing individual results across the three readers, the AI-assisted tool enhanced sensitivity and NPV for all three, but reduced specificity, PPV, and accuracy specifically for cytotechnologists.
- When compared to Microscopy, the AI-assisted tool decreased the overall diagnostic time for all slides (from 130.2-197.3 minutes to 90.5-119.5 minutes) and reduced the mean time per slide (from 1.12-1.70 minutes to 0.78-1.03 minutes).

Table 1. Diagnostic performance and time efficiency across three methods

Reader	Cytopathologist			Cytotechnologist A			Cytotechnologist B		
Method	Microscopy	WSI	AI-assisted	Microscopy	WSI	AI-assisted	Microscopy	WSI	AI-assisted
Sensitivity	76.7%	76.7%	83.3%	93.3%	83.3%	100.0%	76.7%	73.3%	93.3%
Specificity	96.5%	93.0%	96.5%	70.9%	80.2%	54.7%	94.2%	84.9%	75.6%
PPV	88.5%	79.3%	89.3%	52.8%	59.5%	43.5%	82.1%	62.9%	57.1%
NPV	92.2%	92.0%	94.3%	96.8%	93.2%	100.0%	92.0%	90.1%	97.0%
Accuracy	91.4%	88.8%	93.1%	76.7%	81.0%	66.4%	89.7%	81.9%	80.2%
Total time (min)	152.3	133.2	90.5	130.2	170.3	108.9	197.3	187.9	119.5
Mean time (min)	1.31	1.15	0.78	1.12	1.47	0.94	1.70	1.62	1.03

- WSI examination showed a similar overall diagnostic time as Microscopy.
- All readers noted a significant decrease in diagnostic time with the AI-assisted tool compared to both Microscopy and WSI examination.

Conclusion

- In comparison to Microscopy, the AI-assisted tool demonstrated increased sensitivity and NPV, accompanied by a substantial reduction in diagnostic time.
- Variations in performance were observed among the three readers, suggesting that the AI-assisted tool might enhance the clinical contribution of cytotechnologists by helping to interpretate more suspicious cases for subsequent review by the cytopathologist.
- The diagnostic performance and time efficiency of WSI examination were comparable to Microscopy, emphasizing the potential benefits of integrating the AI-assisted tool into digital urine cytology in clinical practice.