Supplementary Information (SI) for Lab on a Chip.
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Table S3 Recent examples of μPADs (2018-2025) for medical diagnostic applications (other targets)
This is an extended version of Table 3 in the main text
Columns not shown in the main text tables are indicated with light blue colour column headings

Sample	Sample matrix	Real sample test	Sample type category	Dimension of channel or area on paper surface	Detection technique	Detection range	Detection limit	Storage stability	Assay time	Number of test zones	Off-device pretreatment	Operation steps	Reagent handling	External equipment	Device cost (USD)	Inventor	Article title	Ref
Uric Acid	Saliva	Clinical sample	4	10 – 80 ppm	Colorimetric	0-27.6,8 ppm (artificial saliva)	0.1 ppm (artificial saliva)	Air-tight seals 4°C >3 months	<10 min	Yes Multiple operations	Pretreatment (surfactant addition, vortex and heating)	Sample application IPA application Water application Imaging	No	Smartphone Black box	10 μL	Outfitted	Digital Quantification Method for Sensitive Point-of-Care Detection of Salivary Uric Acid Using Smartphone-Assisted μPADs	K. Fan, J. Zeng, C. Yang, G. Wang, K. Liao, X. Zhou, Y. Deng and G. Liu, ACS Sens., 2022, 7, 2608-2617
Hemoglobin	Human saliva	Clinical sample	5	0.01–137.40 μg/mL	Colorimetric intensity	1.37–2000 μg/mL	1.37 μg/mL	Sealed Room temperature >3 weeks	3 min	Yes Single reaction	No	Sample application Imaging	No	Mobile phone	38 μL	Enzyme	A Machine-Learning-Driven Cyclic-Optimizing Strategy for the Construction of Paper-Based Microfluidic Devices in the Early Diagnosis of Periodontitis	K. Lu, Y. Zhang, K. Tang, W. Huang, F. Chen, M. Chen, Y. Wang and J. Zhang, ACS Sens., 2025, 10, 7502–7513
Hemoglobin	Human saliva	Clinical sample	5	0.01–137.40 μg/mL	Colored distance	3–200, 200–2000 μg/mL	3 μg/mL	Sealed Room temperature >3 weeks	3 min	Yes Single reaction	No	Sample application Imaging	No	Mobile phone	34 μL	Enzyme	A Machine-Learning-Driven Cyclic-Optimizing Strategy for the Construction of Paper-Based Microfluidic Devices in the Early Diagnosis of Periodontitis	K. Lu, Y. Zhang, K. Tang, W. Huang, F. Chen, M. Chen, Y. Wang and J. Zhang, ACS Sens., 2025, 10, 7502–7513
Albumin	Human urine	Clinical sample	5	3.4–1523.4, 4249 mg/L	Colored distance	0–1000 mg/L (Artificial urine)	N.A.	In a desiccator Room temperature >2 months	15 min	No 15–45 min	No	Dipping	No	No	<3 mL (Zip)	Chelation	Paper-Based Device for Naked Eye Urinary Albumin/Creatinine Ratio Evaluation	R. Hisatka, K. Kuwahara, Y.-C. Wen, T.-H. Yen, T. Hosta, C.-M. Cheng and D. Citters, ACS Sens., 2020, 5, 1110–1118
Creatinine	Human urine	Clinical sample	5	239–2609 mg/L	Colored distance	0–3000 mg/L (Artificial urine)	N.A.	In a desiccator Room temperature >2 months	15 min	No 15–45 min	No	Dipping	No	No	<3 mL (Zip)	Chelation	Paper-Based Device for Naked Eye Urinary Albumin/Creatinine Ratio Evaluation	R. Hisatka, K. Kuwahara, Y.-C. Wen, T.-H. Yen, T. Hosta, C.-M. Cheng and D. Citters, ACS Sens., 2020, 5, 1110–1118
Glucose	Human whole blood	Clinical sample	5	0.4–12.2 mM	Colorimetric	2.5–55 mM (whole blood)	0.3 mM (whole blood)	N.A.	15 min	Yes Single reaction (without kinetic data)	No	Sample application Imaging	No	Smartphone	100 μL	Enzyme	Three-Dimensional Paper-Based Microfluidic Analytical Devices Integrated with a Plasma Separation Membrane for the Detection of Biomarkers in Whole Blood	C. Park, H.-R. Kim, E.-K. Kim, I.-K. Jeong, J.-C. Pyun and S. Park, ACS Appl. Mater. Interfaces, 2019, 11, 36428-36434
Glucose	Human whole blood	Clinical sample	5	63–146 mg/dL	Colorimetric	0–500 mg/dL (PBS)	N.A.	N.A.	30 min	No Multiple operations	No	Sample application and buffer application Imaging	No	Scanner	1 μL	Enzyme	An innovative blood plasma separation method for a paper-based analytical device using chitosan functionalization	D. Kim, S. Kim and S. Kim, Analyst, 2020, 145, 5891-5899
Glucose	Human whole blood	Clinical sample	5	0.1–6.4 mM	Colorimetric	2.25–15.00 mM (whole blood)	0.12 mM (whole blood)	Sealed with a plastic film 4°C >60 days 30°C >8 days 90%	12 min	Yes Single reaction	No	Sample application Imaging	No	Home-made readout device (smartphone)	20 μL	Enzyme	Hydrogel Paper-Based Analytical Devices: Separation Free In Situ Assay of Small Molecule Targets in Whole Blood	J. Su, H. Khan and L. Yang, Anal. Chem. 2021, 93, 14753-14763
Urea	Human whole blood	Clinical sample	5	2.49–38.14 mM (blood)	Colorimetric	2.49–38.14 mM (blood)	0.03 mM (blood)	30°C >8 days 90%	<2 min	Yes Single reaction	No	Sample application Imaging	No	Plastic cartridge Portable optical reader	20 μL	Enzyme	A low-cost paper-based blood urea nitrogen optical biosensor for renal surveillance in Singapore	J. Cheng, Y. Fu, J. Guo and J. Guo, Sens. Actuators B: Chem., 2023, 387, 133795
Uric acid	Human whole blood	Clinical sample	5	0.1786–0.6651 mM	Colorimetric	0–1.5 mM (whole blood)	0.1127 mmol/L (whole blood)	Sealing and light avoidance 4°C >28 days	>10 min	No 10–24 min	No	Sample application Buffer application Imaging	No	Smartphone Box with light source	30 μL	Enzyme	Microfluidic Chip with Integrated Whole Blood Separation for Simultaneous Accurate Quantification of Multiple Chronic Kidney Disease Markers and Long-Term Monitoring	J. Yang, X. Peng, H. Li, P. Chang, S. Ren and S. Li, ACS Sens., 2025, 10, 9823–9832
Creatinine	Human whole blood	Clinical sample	5	88.8–1392.4 μM	Colorimetric	0–100 μM (whole blood)	0.2878 μmol/L (whole blood)	Sealing and light avoidance 4°C >28 days	>13 min	No 13–24 min	No	Sample application Buffer application Imaging	No	Smartphone Box with light source	30 μL	Dye	Microfluidic Chip with Integrated Whole Blood Separation for Simultaneous Accurate Quantification of Multiple Chronic Kidney Disease Markers and Long-Term Monitoring	J. Yang, X. Peng, H. Li, P. Chang, S. Ren and S. Li, ACS Sens., 2025, 10, 9823–9832
Albumin	Human whole blood	Clinical sample	5	33–90.9 mg/mL	Colorimetric	0–100 mg/mL (whole blood)	0.3698 mg/mL (whole blood)	Sealing and light avoidance 4°C >28 days	>6 min	No 6–24 min	No	Sample application Buffer application Imaging	No	Smartphone Box with light source	30 μL	Dye	Microfluidic Chip with Integrated Whole Blood Separation for Simultaneous Accurate Quantification of Multiple Chronic Kidney Disease Markers and Long-Term Monitoring	J. Yang, X. Peng, H. Li, P. Chang, S. Ren and S. Li, ACS Sens., 2025, 10, 9823–9832
Hemoglobin	Human whole blood	Clinical sample	5	N.A.	Colorimetric	2.5–19 μg/dL	2.5 μg/dL	Room temperature >4 hrs	<5 min	No Automated smartphone app	No	Sample application Auto-imaging with smartphone	No	Plastic box Smartphone	around 10 μL (finger-prick)	Enzyme	Smartphone-Enabled Paper-Based Hemoglobin Sensor for Extreme Point-of-Care Diagnostics	S. K. Biswas, S. Chakraborty, S. Bandyopadhyay, S. Kar, N. K. Sore, S. Saha and S. Chakraborty, ACS Sens., 2021, 6, 1077-1085
Cardiac troponin I	Human whole blood	Clinical sample	4	<0.5 – 0.83 ng/mL	Colored distance	0.029–2.5 ng/mL (whole blood)	0.029 ng/mL (whole blood)	Room temperature >10 weeks >80%	15–30 min	No 15–30 min	Sample sterilization	Sample and buffer application	No	No	3 μL	Dye	Rapid Distance-Based Cardiac Troponin Quantification Using Paper Analytical Devices for the Screening and the Follow-Up of Acute Myocardial Infarction, Using a Single Drop of Human Whole Blood	K. Khashormaddaki and M. Dyrsghat, ACS Sens., 2021, 6, 1339-1347
Urea	Human saliva	Diluted clinical sample	3	<0.2/12–2.02 mM	Colorimetric	0.10–5.0 mM	0.032 mM	Under vacuum Room temperature >1 month 90%	35 min	No 20–120 min	10-fold dilution with synthetic saliva	Sample application Sealing Imaging	No	Scanner	15–20 μL	Enzyme	On-hand test for ammonium and urea determination in saliva to monitor chronic kidney disease - Design of a couple of microfluidic paper-based devices	P. T. S. M. Ferreira, R. B. R. Mesquita and A. O. S. S. Rangel, Microchem. J., 2023, 193, 109102
NH4	Human saliva	Diluted clinical sample	3	<0.384–3.01 mM	Colorimetric	0.16–5.0 mM	0.009 mM	Under vacuum Room temperature >1 month 100%	15 min	No 15–60 min	10-fold dilution with synthetic saliva	Sample application NaOH application Sealing Imaging	Yes NaOH	Scanner	15–20 μL	pH change	On-hand test for ammonium and urea determination in saliva to monitor chronic kidney disease - Design of a couple of microfluidic paper-based devices	P. T. S. M. Ferreira, R. B. R. Mesquita and A. O. S. S. Rangel, Microchem. J., 2023, 193, 109102
Zn(II)	Human urine	Spiked into biofluid sample	2	0.119–1.418 mg/L	Colorimetric	60.0–750 μg/L (urine)	10 μg/L (urine)	Room temperature >7 days >80%	>5 min	No 5 min–2 hrs	2-fold dilution	Sample application Imaging	No	Scanner	19 μL	Dye	A microfluidic paper-based analytical device for the determination of zinc(II) in children's urine samples and food also supplement solutions	M. M. P. Melo, A. O. S. S. Rangel and R. B. R. Mesquita, Talanta, 2024, 268, 125893
Histidine	Human urine	Spiked into biofluid sample	2	1–5 mM	PL–pixel	0.5–20 mM	0.021 mM	N.A.	>10 min (drying time not included)	Yes Multiple operations	No	Sample application Curing Peeling off Reagent application PL imaging	Yes BiVO$_4$/Au/Zn-Co^{2+}	Oven or hair dryer Imaging box Home-made Smartphone	7 μL	Coffee ring	Dual-Mode Undistorted Visual Fluorescent Sensing Strategy through Manipulating the Coffee-Ring Effect on Microfluidic Paper-Based Chip	J. Qi, B. Li, D. Lin, Z. Du, L. Pu, X. Wang, Z. Zhang, L. Luo and L. Chen, Anal. Chem., 2023, 95, 10486-10491
Histidine	Human urine	Spiked into biofluid sample	2	1–5 mM	PL–distance	0.5–20 mM	0.5 mM	N.A.	>10 min (drying time not included)	Yes Multiple operations	No	Sample application Curing Peeling off Reagent application PL imaging	Yes BiVO$_4$/Au/Zn-Co^{2+}	Oven or hair dryer Imaging box Home-made Smartphone	7 μL	Coffee ring	Dual-Mode Undistorted Visual Fluorescent Sensing Strategy through Manipulating the Coffee-Ring Effect on Microfluidic Paper-Based Chip	J. Qi, B. Li, D. Lin, Z. Du, L. Pu, X. Wang, Z. Zhang, L. Luo and L. Chen, Anal. Chem., 2023, 95, 10486-10491
Glucose	Human serum	Spiked into biofluid sample	2	0–11 mM	Colorimetric	0–11 mM (serum)	0.2 mM (PBS)	N.A.	8 min (buffer) 8 min (serum)	Yes Single reaction (without kinetic data)	(Blood separation)	Sample application Imaging	No	Camera	500 μL	Enzyme	Double-sided 3D printing on paper towards mass production of three-dimensional paper-based microfluidic analytical devices (3D μPADs)	C. Park, Y. D. Han, H. V. Kim, J. Lee, H. C. Yoon and S. Park, Lab Chip, 2018, 18, 1533-1538
Cholesterol	Human serum	Spiked into biofluid sample	2	2.6–6.7 mM	Colorimetric	2.6–6.7 mM (serum)	0.2 mM (PBS)	N.A.	8 min (buffer) 8 min (serum)	Yes Single reaction (without kinetic data)	(Blood separation)	Sample application Imaging	No	Camera	500 μL	Enzyme	Double-sided 3D printing on paper towards mass production of three-dimensional paper-based microfluidic analytical devices (3D μPADs)	C. Park, Y. D. Han, H. V. Kim, J. Lee, H. C. Yoon and S. Park, Lab Chip, 2018, 18, 1533-1538
Triglyceride	Human serum	Spiked into biofluid sample	2	1–2.3 mM	Colorimetric	1–2.3 mM (serum)	0.2 mM (PBS)	N.A.	8 min (buffer) 8 min (serum)	Yes Single reaction (without kinetic data)	(Blood separation)	Sample application Imaging	No	Camera	500 μL	Enzyme	Double-sided 3D printing on paper towards mass production of three-dimensional paper-based microfluidic analytical devices (3D μPADs)	C. Park, Y. D. Han, H. V. Kim, J. Lee, H. C. Yoon and S. Park, Lab Chip, 2018, 18, 1533-1538
Secretoneurin	Serum	Spiked into biofluid sample	2	0.1–300 μM	PL	0.1–300 μM	N.A. (117 nM in bulk)	N.A.	N.A.	N.A.	(Blood separation)	Sample application Drying PL measurement	No	Smartphone Evolution light	50 μL	PL quenching	Microfluidic Paper-Based Fluorescent Sensing Device Using Citric Acid Derived Carbon Dots/Tungsten Sulfide Sylnanes for On-site Detection of Secretoneurin	S. Arif, M. Hassan, S. Rasheed, N. Ahmad, B. Fatima, S. G. Musharraf and D. Hussain, Biosens. Bioelectron., 2026, 291, 118025
Alkaline phosphatase (ALP)	Cell serum Human serum Goat serum	Spiked into biofluid sample	2	39, 169, 8 U/L	Eriochrome (CA)	1–1000 U/L	1.4 U/L (buffer)	With deoxacol Room temperature >4 weeks >70%	20 min (pre-incubation) 20 min (20 samples flow measurement)	Yes Single reaction	Centrifugation Pre-incubation	Pre-mixing sample and reagent Sample application Eriochrome measurement	Yes (no reagent storage)	Potentiostat	10 μL	Enzyme	Paper-Based Laser-Pyrolyzed Electrofluidics: An Electrochemical Platform for Capillary-Driven Diagnostic Bioassays	L. Beringer, J. M. Leonardi, A. Suea-Ngam, D. A. Richards, A. J. deMello and C.-J. Shih, Adv. Mater., 2023, 35, 2302993
HCO3	Artificial saliva	Spiked into artificial biofluid sample	1	5, 10 μM	Eriochrome (CA)	0.25 μM to 5 mM (PBS)	0.15 μM (PBS)	>4 weeks 82.9%	1.10 s	No Immediate measurement	No	Sample application Eriochrome measurement	No	Potentiostat	~400 μL	Enzyme	Development of an origami-microfluidic paper-based analytical device for highly sensitive detection of dual biomarkers in artificial saliva	C. Chen, B. Ren, B. Liu, Y. Xiao, G. Tang, Y. Shen, J. Liang and Z. Liang, Microchem. J., 2026, 210, 112968
Glucose	Artificial saliva	Spiked into artificial biofluid sample	1	100, 200 μM	Eriochrome (CA)	2.5 μM to 3 mM	1.9 μM	in PBS 4°C >4 weeks 78.4%	1.10 s (only Eriochrome measurement time)	No Immediate measurement	No	Sample application Eriochrome measurement	No	Potentiostat	~400 μL	Enzyme	Development of an origami-microfluidic paper-based analytical device for highly sensitive detection of dual biomarkers in artificial saliva	C. Chen, B. Ren, B. Liu, Y. Xiao, G. Tang, Y. Shen, J. Liang and Z. Liang, Microchem. J., 2026, 210, 112968
Glucose	Artificial saliva	Spiked into artificial biofluid sample	1	19–200 mg/dL	Colored distance (hue/sat)	19–200 mg/dL (artificial saliva)	19 mg/dL (artificial saliva)	N.A.	60 min	Yes Multiple operations	No	Sample application Drying Smartphone readout	No	Smartphone	80 μL	Enzyme	Development of a Semi-quantitative Remote Readout Approach for Paper-Based Analytical Devices (PADs) for Enzymatic H2O2 and Glucose Detection	Y. Mamiana, S. Kitagawa, Y. Hosta and D. Citters, Anal. Chem., 2026, 97, 1580-1586
Glucose	Artificial urine	Spiked into artificial biofluid sample	1	1–100 mM	Colorimetric	0–20 mM (artificial urine)	1 mM (artificial urine)	N.A.	10–30 min	No No color degradation	No	Sample application	No	No	80 μL or 2 drops	Polymer degration	Traffic light type paper-based analytical device for intuitive and semi-quantitative naked-eye signal readout	S. Chia, R. Hisatka, Y. Hosta and D. Citters, Lab Chip, 2022, 22, 717-726
Ascorbic acid	Artificial urine	Spiked into artificial biofluid sample	1	0.1135 mM	Eriochrome (CA)	0.16–0.8 mM (PBS, carbo buffer)	92.6 μM (PBS, carbo buffer)	N.A.	250 s	No Immediate measurement	No	Sample application Eriochrome measurement	No	Potentiostat	1 μL	Outfitted	3D Capillary-Driven Paper-Based Sequential Microfluidic Device for Electrochemical Sensing Applications	A. Yakoh, S. Chaipo, W. Siangproh and O. Chailapakul, ACS Sens., 2019, 4, 1211-1221
Lithium ion	Human whole Blood (1.25-fold diluted)	Spiked into diluted biofluid sample	2	0–2.5 mM	Colorimetric	0–2.5 mM (whole blood)	0.281 mM (whole blood)	N.A.	10 s (does not include blood wicking time)	No Immediate measurement	No	Sample application Placement of detection unit Imaging	No	(Camera)	10–20 μL	Dye	Paper-Based Device for the Facile Colorimetric Determination of Lithium Ions in Human Whole Blood	T. Komatsu, M. Maeki, A. Ishida, H. Tani and M. Tokeshi, ACS Sens., 2020, 5, 1267-1264
DNA adenine methylation Mtase (Dam MTase)	Human serum (5-fold diluted)	Spiked into diluted biofluid sample	2	30–70 U/mL	FL	1.0–80 U/mL (buffer)	0.11 U/mL (buffer)	>10 days	30 min	Yes Multiple operations	(Blood separation)	Pre-mixing of sample and reagent Sample application Reagent addition PL measurement	Yes Fluorescent dye	FL meter	~7 μL (no details)	Enzyme	Paper-based fluorescence strip with unidirectally anchored dimeric G-quadruplex-coupled DNA tetrahedron-structured probe for sensing DNA methyltransferase	M. Wang, J. Qi, F. Li, Y. Liu, J. Yang, B. Li, X. Zhuang, L. Chen and X. Pu, Sens. Actuators B: Chem., 2026, 448, 139643
Nicotinamide adenine dinucleotide phosphate (NADPH)	Simulated urte Human serum (10-fold diluted)	Spiked into diluted biofluid sample	2	0.01–1.0 mM	Eriochrome (CA)	0.01–1.0 mM, 1.0–4.0 mM (urine and serum)	3.75 μM (buffer)	Sealed in aluminum bags 4°C >7 days (ambient condition for 56 days) 99.8%	<10 min (5 samples with flow measurement)	No Immediate measurement	No	Buffer application Sample application Eriochrome measurement	No	Potentiostat	10 μL	Outfitted	Paper-Based Feed-Flow Electrochemical Device Enabling Self-Calibrated and High-Throughput NADPH Measurements	N. Thunkiatkun, L. Hongtawee, U. Boonyasri, A. Yakoh and K. Chaiseeharitaron, Anal. Chem., 2026, 97, 20771-20779
L-Tryptophan (Trp)	Human serum (depyrinated) Human urine (centrifuged and 10-fold diluted)	Spiked into diluted biofluid sample	2	0.079–0.126 mM	Colorimetric	0.26–1.0 mM	220.7 μM	N.A.	15 min	Yes Multiple operations	(Blood separation)	Sample application Centrifugation twice Reagent application Imaging	Yes ZIF-8/Hb-MIP-Cel Au-Nim-CL-Alb	Centrifuge Smartphone	N.A.	AuNP aggregation	Paper-based microfluidic system and chiroptical functionalized gold nano-seal for colorimetric detection of L-Tryptophan	M. Karimian, K. Zeeshan, R. Zare-Dorabei and S. Nemati, Anal. Chem. Acta, 2026, 1265, 343222
Albumin	Human serum (2-fold diluted)	Spiked into diluted biofluid sample	2	1.0–18.0 g/L	Colored distance, angle	1–25 g/L (PBS)	0.8 g/L (PBS)	N.A.	30 min	No 30–40 min	(Blood separation)	Sample and buffer application	No	No	9 μL	Dye enzyme	Distance-Based Paper Device for a Naked-Eye Albumin-to-Alkaline Phosphatase Ratio Assay	K. Phoonsawat, K. Khachornsakul, N. Rakwanthon, C. S. Henry and W. Dungchai, ACS Sens., 2021, 6, 3047-3055
Alkaline phosphatase (ALP)	Human serum (2-fold diluted)	Spiked into diluted biofluid sample	2	12.5–145.0 U/L	Colored distance, angle	0–50 U/L and 50–200 U/L (PBS)	1.9 U/L (PBS)	N.A.	30 min	No 30–40 min	(Blood separation)	Sample and buffer application	No	No	9 μL	Dye enzyme	Distance-Based Paper Device for a Naked-Eye Albumin-to-Alkaline Phosphatase Ratio Assay	K. Phoonsawat, K. Khachornsakul, N. Rakwanthon, C. S. Henry and W. Dungchai, ACS Sens., 2021, 6, 3047-3055
Serotonin (5-HT)	Buffer	N.A.	-	N.A.	Eriochrome (CA)	1–20 mM (PBS)	0.18 mM (PBS)	N.A.	13 min	Yes Multiple operations	N.A.	Reagent application Drying Sample application Mixing PAD Eriochrome measurement	Yes KIO$_3$/CL	Potentiostat	1 μL	Outfitted	3D Capillary-Driven Paper-Based Sequential Microfluidic Device for Electrochemical Sensing Applications	A. Yakoh, S. Chaipo, W. Siangproh and O. Chailapakul, ACS Sens., 2019, 4, 1211-1221
Cardiac troponin I (cTnI)	PBS	N.A.	-	N.A.	SERS	0–0.5 ng/ mL (PBS)	0.02 ng/mL (PBS)	N.A.	<60min	No Automated sequential reagent addition	N.A.	Sample and buffer application SERS measurement	No	SERS spectrophotometer	75 μL	Aptamer	Paper Microfluidic Device with a Horizontal Motion Valve and a Localized Delay for Automatic Control of a Multistep Assay	D. Tu, A. Holekey, J. Dean, S. Mabbott and G. L. Cote, Anal. Chem., 2021, 93, 4287-4905

*estimated from figures