Supplementary Information (SI) for Lab on a Chip.
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Table S2 Recent examples of µPADs (2018-2025) for medical diagnostic applications (nucleic acid testing)
This is an extended version of Table 2 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 sets (pcs)	Number of analytes (pcs)	Detection technique	Detection range	Detection limit	Storage stability	Assay time	Number of steps (pcs)	PA device pretreatment	Operation steps	Reagent handling	External equipment	Cost of device (euro)	Article title	Ref
Circulating tumor DNA (ctDNA)	Mice serum	Clinical sample (mice)	4	N.A.	Colorimetric	200–1000pM (serum)	90.91 pM (serum)	4°C: >1.5 days; -18°C: >50%	60 min (on strip)	Very Simple: Single operations	Blood separation Blood lysis Annealing Pre.-nite latch probe	Pre-mixing of sample and reagent Sample application Sample incubation Cutting device Reagent application Heating Pre-mixing of sample and reagent	Yes Hemolysis Dilute TMB H_2O_2	Culture dish Incubator Smartphone 3D printed dark box	2.5 pc.	Pop-Up Paper-Based Biosensor for a Dual-Mode Lung Cancer ctDNA Assay Based on Novel Cuft Nanostrands with Dual-Enzyme Activities and a Portable Smartphone/Bameter for Readout	S. Yang, J. Zhu, L. Yang, H. Fu, Y. Wang, D. Hao, C. Hou, D. Zhong and M. Yang, ACS Sens., 2025, 10, 153-147
Circulating tumor DNA (ctDNA)	Mice serum	Clinical sample (mice)	4	N.A.	60 min (on strip)	200–1000pM (serum)	79.98 pM (serum)	4°C: >1.5 days; -18°C: >50%	60 min (on strip)	Very Simple: Single operations	Blood separation Blood lysis Annealing Pre.-nite latch probe	Pre-mixing of sample and reagent Sample application Sample incubation Cutting device Reagent application Heating Pre-mixing of sample and reagent	Yes Hemolysis Dilute TMB H_2O_2	Culture dish Incubator Smartphone Manometer Gas pressure meter	~2.5 pc. (on details)	Pop-Up Paper-Based Biosensor for a Dual-Mode Lung Cancer ctDNA Assay Based on Novel Cuft Nanostrands with Dual-Enzyme Activities and a Portable Smartphone/Bameter for Readout	S. Yang, J. Zhu, L. Yang, H. Fu, Y. Wang, D. Hao, C. Hou, D. Zhong and M. Yang, ACS Sens., 2025, 10, 153-147
SARS-CoV-2	Human saliva	Clinical sample	5	N.A.	Colorimetric	N.A.	50 copies/µL (saliva)	N.A.	60 min	Very Simple: Automated sequential reagent addition	No	Sample, reagent, and buffer application Sealing Water pouring	Yes Proteinase K Amplification-related reagent (without primers)	IR module (no power supply)	20 pc.	Point-of-Care Toehold for Multiplex Molecular Diagnosis of SARS-CoV-2 and Influenza A and B Viruses	S. Lee, C.-H. Cho and A. P. Eatenglo, ACS Sens., 2021, 6, 3204-3213
SARS-CoV-2	Swab sample	Clinical sample	4	N.A.	PL	10^2–10^7 copies	10^2 copies	Room temperature: >10 days	20 min (off-strip) 40 min (on-strip)	Very Simple: Single reaction (without clear kinetic data)	RNA extraction	Sealing Sample collection Sample application	Yes Amplification-related reagent	Heating plate PL reader	1 pc.	Autonomous lab-on-paper for multiplexed, CRISPR-based diagnostics of SARS-CoV-2	K. Yin, X. Ding, Z. Li, M. B. Ellis, E. Ballesteros and C. Liu, Lab Chip, 2021, 21, 2730-2737
SARS-CoV-2	Swab sample	Clinical sample	4	N.A.	Extract (enzymatic)	0.05–100 nM (PBS)	0.12 pM (PBS)	4°C: >6 weeks; -80,-110 °C	>20 min (extraction) 52 min (on-strip)	Very Simple: Single operations	RNA extraction	Sample application Buffer application Device assembly Reagent application Enzyme measurement	Yes $Fe(CN)_6^{3-/4-}$	Potentiostat	3 pc.	Peptide nucleic acid probe-assisted paper-based electrochemical biosensor for multiplexed detection of respiratory viruses	A. Lomas, K. Tantayapak, P. Preechakasedkit, E. Pasomsub, T. Gao, C. S. Henry, D. Citeker, T. Vilaiam, O. Chailapakul and N. Ruecha, Talanta, 2024, 279, 126513
SARS-CoV-2	Swab sample	Clinical sample	4	N.A.	Colorimetric	3.68–118,056 copies/µL	N.A.	4°C: >6 weeks; -80,-110 °C	>30 min	Very Simple: Single operations	RNA extraction	Sample application Folding for three times Reagent application Heating	No	3D printed attachment (Oneophone)	5 pc.	A paper-based assay for the colorimetric detection of SARS-CoV-2 variants at single-nucleotide resolution	T. Zhang, R. Deng, Y. Wang, C. Wu, X. Zhang, C. Wang, N. Dong, R. Lukeesuhasan, S. Tang, C. Tang, T. Xue, Y. Zhang, Y. Hu, Q. Hu, W. Li and J. Li, Nat. Biomed. Eng., 2022, 6, 957-967
Human papillomavirus (HPV)	Swab sample	Clinical sample	4	N.A.	PL	1.–1.5^{4} fM	1 fM	N.A.	30 min	Very Simple: Single operations	RNA extraction Reverse transcription and digestion	Sample and RgEnh application Sample and water Folding and reagent addition PL imaging	Yes RgEnh FDA-aaRNA-quencher	Incubator Black box Portable fluorescence detector	5 pc.	CRISPR/Cas on Microfluidic Paper-Based Analytical Devices for Point-of-Care Screening of Cervical Cancer	S. Liu, T. Yu, L. Song, K. Kalantar-Zadeh and B. Liu, ACS Sens., 2020, 10, 4595–4570
Human papillomavirus (HPV) subtypes	Swab sample	Clinical sample	4	N.A.	PL	N.A.	1.–103 aM	N.A.	40 min	Very Simple: Single operations	DNA extraction Pre.-amplification	Sample application Sealing PL imaging	Yes Amplification-related reagent	Heater PL reader	7.5 pc.	Programmable Multiplexed Nucleic Acid Detection by Harnessing Specificity Defect of CRISPR/Cas Cis	X. Guan, R. Yang, J. Zhang, J. Moon, C. Hao, C. Guo, L. Jiang, D. Suanda, D. S. Roberts, R. LaRuke and C. Liu, Adv. Sci., 2020, 12, 2011021
Influenza (H1N1)	Swab sample	Clinical sample	4	N.A.	Extract (enzymatic)	0.05–1000 nM (PBS)	0.05 pM (PBS)	4°C: >6 weeks; -80,-110 °C	>20 min (extraction) 52 min (on-strip)	Very Simple: Single operations	RNA extraction	Sample application Buffer application Device assembly Reagent application Enzyme measurement	Yes $Fe(CN)_6^{3-/4-}$	Potentiostat	3 pc.	Peptide nucleic acid probe-assisted paper-based electrochemical biosensor for multiplexed detection of respiratory viruses	A. Lomas, K. Tantayapak, P. Preechakasedkit, E. Pasomsub, T. Gao, C. S. Henry, D. Citeker, T. Vilaiam, O. Chailapakul and N. Ruecha, Talanta, 2024, 279, 126513
Respiratory syncytial virus (RSV)	Swab sample	Clinical sample	4	N.A.	Extract (enzymatic)	10.–1000 nM (PBS)	0.56 pM (PBS)	4°C: >6 weeks; -80,-110 °C	>20 min (extraction) 52 min (on-strip)	Very Simple: Single operations	RNA extraction	Sample application Buffer application Device assembly Reagent application Enzyme measurement	Yes $Fe(CN)_6^{3-/4-}$	Potentiostat	3 pc.	Peptide nucleic acid probe-assisted paper-based electrochemical biosensor for multiplexed detection of respiratory viruses	A. Lomas, K. Tantayapak, P. Preechakasedkit, E. Pasomsub, T. Gao, C. S. Henry, D. Citeker, T. Vilaiam, O. Chailapakul and N. Ruecha, Talanta, 2024, 279, 126513
Hepatitis B virus	Human serum	Clinical sample	4	0.27–0.39 kg copies/µL	Extract (SWV)	10 pM to 2 µM (PBS)	7.23 pM (PBS)	4°C: >1 month (-1.0%)	7 min	Very Simple: Single reaction Automated sequential reagent addition	(Blood separation) DNA extraction	Sample application Buffer application Reagent application Enzyme measurement	No	Potentiostat	200 pc. (off-strip) 50 pc. (on-strip)	Amplification-free DNA Sensor for the One-Step Detection of the Hepatitis B Virus Using an Automated Paper-Based Lateral Flow Electrochemical Device	C. Sitarman, A. Yatsh, N. Chauzyan, P. Tarnjitpunnith, T. Vilaiam and O. Chailapakul, Anal. Chem., 2021, 93, 2879-2887
Dengue virus (DRN)	Human serum	Clinical sample	4	N.A.	Colorimetric	5 copies (serum)	>50°C: >50 hr	>50 min	Very Simple: Single operations	Blood separation		Pre-mixing sample and 1pcs buffer Sample application Washing for three times Reagent application Buffer application Reagent application Heating	Yes 1pcs buffer Ethanol Amplification-related reagent	Waste container Portable heater	~60 pc.	All-Serotype Dengue Virus Detection through Multilayered Origami-Based Paper/Polymer-Microfluidics	P. Biseau, G. N. Moitumber Solechana, T. N. Ramprasad, P. Gopal, D. Mehak, A. K. Ghosh and S. Chakraborty, ACS Sens., 2022, 7, 3700-3708
Dengue virus	Human serum	Clinical sample	4	N.A.	PL	N.A.	10 copies (serum)	N.A.	<1 hr	Very Simple: Single operations	(Blood separation) DNA extraction on different devices	Sample and buffer application Sample collection Sample application Sample transfer Sample application Heating Sample and buffer application Sample collection Sample application Sample transfer Sample application Heating	Yes NaOH	Humid petri dish Heater Fluorescence reader	20 pc.	Paper-based nucleic acid testing system for simple and early diagnosis of mosquito-borne RNA viruses from human serum	M. S. Bukale, Y. Sasti and M. G. Kim, Biosens. Bioelectron., 2020, 151, 111958
Zika virus	Human serum	Clinical sample	4	N.A.	PL	N.A.	10 copies (serum)	N.A.	<1 hr	Very Simple: Single operations	(Blood separation) DNA extraction on different devices	Sample and buffer application Sample collection Sample application Sample transfer Sample application Heating Sample and buffer application Sample collection Sample application Sample transfer Sample application Heating	Yes NaOH	Humid petri dish Heater Fluorescence reader	20 pc.	Paper-based nucleic acid testing system for simple and early diagnosis of mosquito-borne RNA viruses from human serum	M. S. Bukale, Y. Sasti and M. G. Kim, Biosens. Bioelectron., 2020, 151, 111958
Let-7a (miRNA)	Human serum	Diluted clinical sample	3	N.A.	BL	2 fM to 53 pM	1.7 fM	Dilize gel dehydration: Room temperature: >3 months	>5 min (off-strip) 150 min (on-strip)	Very Simple: Single operations	RNA extraction (Blood separation) 2.5 times dilution with water	Sample application Overlapping paper dilu Reagent application Heating Sample application Sealing BL imaging	Yes Isothermal	Incubator 3D printed dark box Smartphone	20 pc.	Portable and Field-Ready Detection of Circulating MicroRNAs with Paper-Based Bioinstrument Screening and Isothermal Amplification	Y. Li, L. Zhou, W. Ni, Q. Luo, C. Zhu and Y. Wu, Anal. Chem., 2019, 91, 14836-14841
SARS-CoV-2	Human saliva	Spiked into lentiform sample	2	6 pM	BL	N.A.	40 nM (50 % (n)-saliva)	Sealed bags: Room temperature: >7 weeks	7.–12 min	Very Simple: Single reaction	(RNA extraction)	Sample application Sealing BL imaging	No	3D printed cassette Camera	10 pc.	Towards detection of SARS-CoV-2 RNA in human saliva: A paper-based miEtec lentiform with a visual bioinstrument output	J. P. Hunt, E. L. Zhao, T. J. Frey, M. Sobieri, C. J. Wan, A. B. Benedict, M. K. Takahashi, J. S. Griffith, M. G. Pitt and B. C. Bundy, N. Biotechnol., 2022, 68, 53-60
Influenza A viruses	Saliva	Spiked into lentiform sample	2	0.5-5000 copies/µL	Colorimetric	N.A.	50 copies/µL (saliva)	N.A.	60 min	Very Simple: Single reaction Automated sequential reagent addition	No	Sample, reagent, and buffer application Sealing Water pouring	Yes Proteinase K Amplification-related reagent (without primers)	IR module (no power supply)	20 pc.	Point-of-Care Toehold for Multiplex Molecular Diagnosis of SARS-CoV-2 and Influenza A and B Viruses	S. Lee, C.-H. Cho and A. P. Eatenglo, ACS Sens., 2021, 6, 3204-3213
Influenza B viruses	Saliva	Spiked into lentiform sample	2	0.5-5000 copies/µL	Colorimetric	N.A.	50 copies/µL (saliva)	N.A.	60 min	Very Simple: Single reaction Automated sequential reagent addition	No	Sample, reagent, and buffer application Sealing Water pouring	Yes Proteinase K Amplification-related reagent (without primers)	IR module (no power supply)	20 pc.	Point-of-Care Toehold for Multiplex Molecular Diagnosis of SARS-CoV-2 and Influenza A and B Viruses	S. Lee, C.-H. Cho and A. P. Eatenglo, ACS Sens., 2021, 6, 3204-3213
HIV-1	Human whole blood	Spiked into lentiform sample	2	3.–3x10^{4} copies/mL	PL	N.A.	3 × 10^{4} copies/mL (whole blood)	N.A.	30 min (extraction) >10 min (post-amplification)	Very Simple: Single operations	Post-DNA isothermal amplification	Sample application Sample and buffer application Sealing Buffer application Reagent application Transfer to RPA pellet Sample application	Yes Amplification-related reagent	Cleaver Microwave Heater PL reader	33 pc.	Nucleic-acid sample preparation from whole blood in a paper-microfluidic device using isolate/cryoprotects	B. P. Sullivan, A. T. Renzer, D. N. Nguyen, J. Y. Zhang and J. D. Posner, J. Chromatogr. B, 2021, 1183, 123486
MRSA	Blood	Spiked into lentiform sample	2	53 copies	PL	1.–1.4^{4} copies (30 min) 10^{2}–10^{7} copies (30 min)	1 copy (30 min)	Room temperature: >30 days; 81.-20%	30 or 45 min	Very Simple: Single reaction (without clear kinetic data)	DNA extraction	Sample and water application Sealing Reac.-time PL measurement	No	Heater PL reader	1 pc.	Fluorometric Paper-Based, Loop-Mediated Isothermal Amplification Devices for Quantitative Point-of-Care Detection of Methicillin-Resistant Staphylococcus aureus (MRSA)	I. Chonpate, A. Suea-Ngam, T. Teethaisong, P. S. Howes, M. Bamkaitiam, A. Laosatpaiwithid, S. Thongthiem, D. Wongsawaeng, a. J. Demello, D. Dean and N. Sonkoosong, ACS Sens., 2021, 6, 712-721
Chikungunya	Human serum	Spiked into lentiform sample	2	N.A.	PL	N.A.	10 copies (serum)	N.A.	<1 hr	Very Simple: Single operations	(Blood separation) DNA extraction on different devices	Sample and buffer application Sealing Sample collection Sample application Sample transfer Sample application PL measurement	Yes NaOH	Humid petri dish Heater PL reader	20 pc.	Paper-based nucleic acid testing system for simple and early diagnosis of mosquito-borne RNA viruses from human serum	M. S. Bukale, Y. Sasti and M. G. Kim, Biosens. Bioelectron., 2020, 151, 111958
SARS-CoV-2	N.A. (aerosol generated by breathing simulator)	Spiked into artificial lentiform sample	1	50.-5×10^{4} copies	Colorimetric	N.A.	17 aM	N.A.	30 min (sample collection) ~1.5 h (on-strip)	No: Automated sequential reaction	No	Sample collection Sealing	No	No	No (mask)	Wearable materials with embedded synthetic biology sensors for biomolecule detection	P. Q. Nguyen, L. R. Soenksen, N. M. Donghia, N. M. Angenent-Mari, H. De Puig, A. Huang, R. Lee, S. Slomovic, T. Galbersanio, G. Lansbury, H. M. Sallum, E. M. Zhao, J. B. Niemi and J. J. Collins, Nat. Biomedical, 2021, 5, 1368-1374
Pathogens DNA (E. coli, S. aureus, P. aeruginosa, K. pneumoniae, A. baumannii)	Stools (sensitizing bacterial contamination on bacteria)	Spiked into artificial lentiform sample	1	10^{2}–10^{7} CFU/mL	PL	1.–1.5^{4} copies/ µL (PBS)	1 copy/µL (PBS)	N.A.	>60 min	Very Simple: Single operations	No	Sample and buffer application Folding on a tower Reagent application PL imaging	Yes Amplification-related reagent	Heater Plastic case Digital fluorescence detection module	20 pc.	An integrated and paper-based microfluidic system employing LAMP-CRISPR and equipped with a portable device for simultaneous detection of pathogens	B. Cai, K. Wang, Y. Yang, X. Lu and X. Li, Anal. Bioanal. Chem., 2024, 417, 785-797
HIV-1	Human whole blood: 0.25 bbl diluted with buffer	Spiked into diluted lentiform sample	1	3 × 10^{4} copies	Colorimetric	N.A.	3 × 10^{4} copies (whole blood)	In bags with silica gel desiccant: Room temperature: >3 months	60 min	No: Custom-designed electronic device controlled	(RNA extraction)	Sample application Buffer application Heating	No	Portable heater and circuit	75 pc.	Microfluidic rapid and autonomous analytical device (microRAD) to detect HIV from whole blood samples	B. A. Phillips, T. J. Mackling, K. F. K. Ejendal, D. S. Hobbs, M. M. Byars, L. J. Baeing, L. G. Jerdonaldi, J. R. Bennett, L. K. Lin, L. S. Barnes and J. C. Linnes, Lab Chip, 2019, 19, 3375-3386
Mpox virus	Artificial saliva or saliva (25-fold diluted)	Spiked into diluted lentiform sample	1	1.–100 pM	Colorimetric	10.–1000 copies/mL (urine, saliva)	<5 copies/mL (urine, saliva)	55°C: >50 days; -20°C: >50%	>30 min	Very Simple: Single operations	DNA extraction Annealing Pre.-incubation	Pre-mixing sample and reagent Pre-mixing two reagents separately Pre-mix above two solutions Reagent application Heating	Yes $AgNO_3$ Urease	Incubator Microtubes Colorimeter	200 pc.	Intended Mismatch DNA Nanosomplexes for Ultrasensitive, Enzymatic Colorimetric Detection of MPOX Virus in Minutes Using a Paper-Based Fast-Flow Micromixing Device	L. Hongtanna, S. Chaiya, N. Wu and A. Yakich, Adv. Healthc. Mater., 2025, 14, 2404233
HPV16	N.A.	N.A.	-	N.A.	Extract (SWV)	N.A.	1 copy/µL	N.A.	150 min	Very Simple: Single operations	(DNA extraction) Pre.-amplification Pre.RPA amplification Pre.CRISPR reaction	Sample application Buffer application Reagent application and reagent Sample, buffer and reagent application Enzyme measurement	Yes (no reagent storage)	Potentiostat	10 pc.	Paper-Based Loop-Prompted Electrochemical Platform for Cas/Bst/Crispr Diagnostic Bioassays	L. Baetrge, J. M. Lorenzi, A. Suea-Ngam, D. A. Richards, A. J. deMello and C. J. Stirk, Adv. Mater., 2023, 35, 2302860
Human papillomavirus (HPV)	Buffer	N.A.	-	N.A.	Extract (personal glucose meter)	N.A.	57 pM	Aluminium-coated pouches with silica gel: Room temperature: >6 months	120 min	Very Simple: Single operations	(DNA extraction)	Sample application Film removal Reagent application Enzyme measurement	No	Personal glucose meter	10 pc.	Paper-based analytical device for point-of-care nucleic acid quantification combining CRISPR/Cas9 and a personal glucose meter	Y. Tanbiji, D. Tong, Y. Hoxie and D. Citeker, Analyst, 2024, 149, 4552-4559
Ebola virus	Water	N.A.	-	N.A.	Colored length	N.A.	11 aM (water)	N.A.	240 min	Very Simple: Single operations	Pre-incubation of CRISPR reaction	Pre.-incubation Dilution Sample application Resistance measurement	Yes Amplification-related reagent CRISPR-related reagent	Incubator Digital Multimeter	5 pc.	Programmable CRISPR-responsive smart materials	M. A. English, L. R. Soenksen, R. V. Gayet, H. de Puig, N. M. Angenent-Mari, A. S. Mao, P. Q. Nguyen and J. J. Collins, Science, 2019, 365, 780-78