Paper-based skin patch for the diagnostic screening of cystic fibrosis

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Materials and Instruments

DE 81 Ion exchange paper and Chr 1 paper (Whatman, GE, US); 1624W Tegaderm and Scotch tape (3M, US); Pilocarpine Nitrate (meets USP test specifications), Sodium Chloride, Sodium L-lactate, and Sodium Bicarbonate (Sigma-Aldrich, US); pH test paper with a range of 1 to 14 (Hangzhou Special Paper Co., Ltd, China); GC-YS-107 Water Sensitive Ink (Gocolor S.Z. Chemical Co., Ltd, China); MK40 Softbox for providing a controlled light source (Shentu, China); ABL850 Analyzer (Radiometer, Danmark); Hole Punchers with the size of 2 mm, 4 mm and 5 mm; Samsung GT-I9300; Canon Powershot A700.
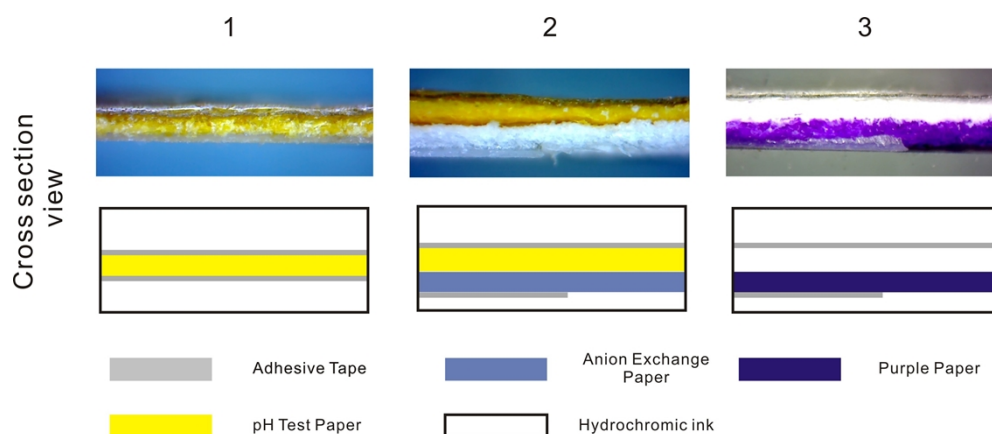
Figure S1. The cross-sectional schematics and images of three sections of the paper-based skin patch. The images also show part of holes on the adhesive tape.
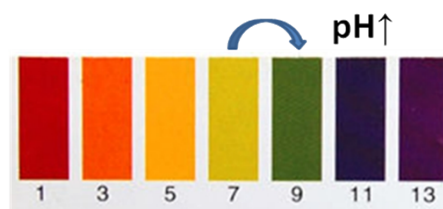

Figure S2. The schematics show the range of the pH test paper. The blue arrow indicates the color change of the section 2 of the skin patch.
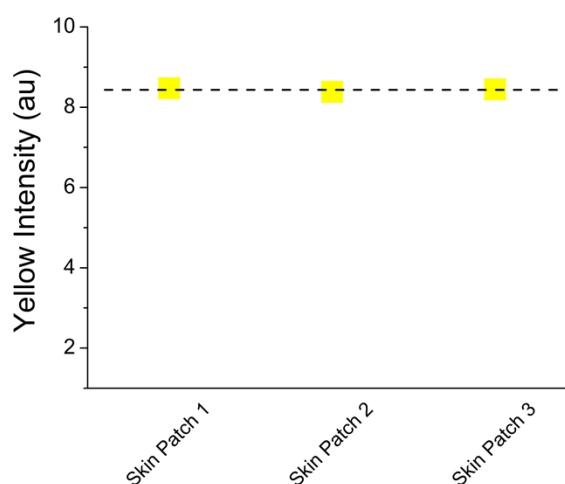

Figure S3. The mean intensity of yellow color (in CMYK) of the section 1 of three skin patches in the controlled light box. The color intensity shows a high consistency with a CV of 0.5%, demonstrating a controlled light source. The dash line indicates the average intensity.
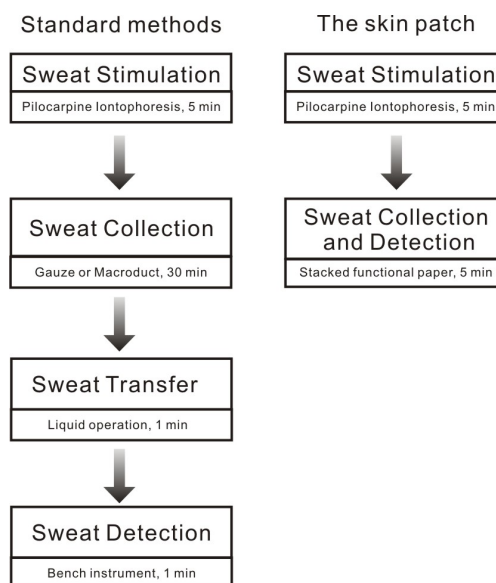
Figure S4. The different operating procedures of standard diagnostic methods and the paper-based skin patch. The standard methods have multiple steps involving lenghy collection and troublesome liquid transfering. On the contrary, the skin patch has streamlined and integrated steps, showing more efficiency and less risk of evaperation errors.
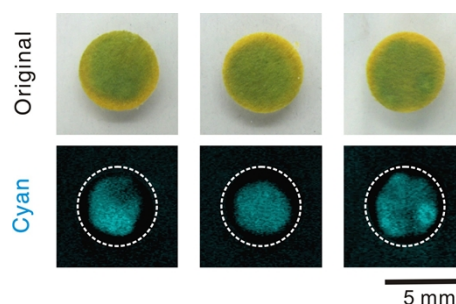

Figure S5. Triplicate experiments of detecting chloride solution (1.5 µL, 100 mM) on the skin patch. The coefficient variation is about 9.6%.
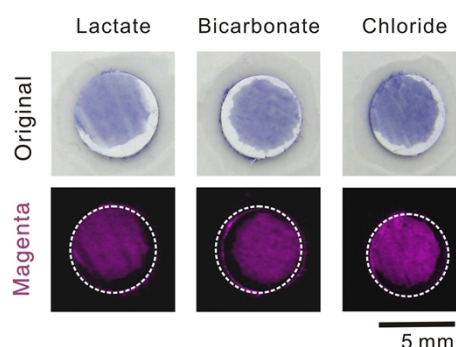

Figure S6. The cholorimetric results of measuring volume of differet anion solutions (1.5µL, 10 mM) on the section 3 of the skin patch. Because the hydrochromic ink is specifically triggered by water, the measured volume seems not to be influnced by anions. The coefficient variation is about 13.8% that is similar to the overall variations of color (magenta) detection.

Table S1. Technical comparison of the skin patch and the reference methods

	Paper-based Skin Patch	Reference methods	
		Gibson-Cooke QPIT	Wescor Macroduct Sweat-Chek system
Analytical Targets	Anions	Chloride	Anions
Detection mechanism	Colorimetric	Coulometry	Conductivity
Overall Coefficient of Variation	~ 15%	< 5% [a]	< 2 % [b]
Coefficient of Determination [c]	0.97	0.99	NA
Dynamic Range	0 to 140 mM (equivalent NaCl)	30 to 900 mM [a]	0 to 150 mmol/L (equivalent NaCl) [b]
Assay Time (min) — Stimulation	5		
Assay Time (min) — Collection / Detection	~ 5	38 to 95 [d]	38 to 71[d]
Cost (US $)	~ 0.62 [f]	22 [d]; 17 [e]	20 [d]; 32 [e]

[a] Product data sheet of ABL 850L; [b] Product data sheet of Sweat-Chek Analyzer; [c] Standard chloride solutions in Fig. 2. [d] J Pediatr (Rio J), 2010, 86(2): 109-114; [e] Clin. Biochem., 2009, 42: 1260–1264; [f] Details in Table S2;

Table S2. Shelf life and material cost of the skin patch

	Shelf life [a]	Quantity	Cost (US $)	For one skin patch	
				Quantity	Cost (US $)
Tegaderm 1624W	3 years	One piece	0.5	One piece	0.5
Hydrochromic ink	> 12 months below 30 °C	25 mL	16	100 μL	0.064
Anion exchange Paper	NA	400 pieces	102.28	One-sixth piece	0.043
Adhesive Tape	NA	32.9 meter	2.67	50 mm	0.004
Chr 1 paper	NA	100 meter	30.57	5 mm	0.0015
pH test Paper (1-14)	NA	80 pieces	0.17	One-third piece	Negligible
Sum	1 year				**~ 0.62**

[a] Product data sheets.

Table S 3. Clinical comparison of the skin patch and the reference method [a]

Patients	Age	Gender	Clinical Diagnosis		Diagnostic Accuracy
			Skin patch (80 mM cutoff)	QPIT (60 mM cutoff)	
A	16	Female	Non-CF	Non-CF	Consistency
B	31	Female	Non-CF	Non-CF	Consistency
C	40	Female	Non-CF	Non-CF	Consistency
D	29	Male	Non-CF	Non-CF	Consistency
E	14	Male	Non-CF	Non-CF	Consistency
F	39	Female	Non-CF	Non-CF	Consistency
G	11	Male	CF	CF	Consistency
H	10	Female	CF	CF	Consistency

[a] Respirology, 2015, 20, 312.

Table S4. Recovery of the instrumental analyzer for detecting chloride [a]

Chloride Concentraion (mM)	10	20	30	40	50	60	70	80	100	120	140
Recovery (%)	0 [b]	65	76	82	86	90	94	91	92	95	94

[a] ABL 850L; [b] Not detecable