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HAL Authorization

1 **Performance of an automated and combined HIV, HBV, HCV, and syphilis**
2 **testing among illegal gold miners in French Guiana using a standardized dried**
3 **blood device**

4

5 Amandine PISONI¹, Elisa REYNAUD², Maylis DOUINE³, Louise HUREAU³, Carmen ALCOCCER CORDELLAT²,
6 Roxane SCHAUB³, Dennis POLAND⁴, Richard MONKEL⁴, Joan LOMMEN⁴, Konstantin YENKOYAN⁵,
7 Stephen VREDEN⁶, Mathieu NACHER³, Edouard TUAILLON^{1*}

8

9 1. Pathogenesis & Control of Chronic and Emerging Infections, Institut National de la Santé et de la Recherche
10 Médicale (INSERM), U1058, Établissement Français du Sang (EFS), Montpellier University and Laboratory of
11 Virology, Centre Hospitalier Universitaire de Montpellier, France.

12 2. Montpellier University Hospital, Montpellier, France.

13 3. Centre d'Investigation Clinique Antilles-Guyane (Inserm 1424), Cayenne Hospital, Epidemiology of Tropical
14 Parasitoses, EA 3593, Université de Guyane, Cayenne, French Guiana.

15 4. Labonovum, Limmen, Netherlands.

16 5. Department of Biochemistry, Neuroscience Laboratory, Cobrain Center Yerevan State Medical University
17 named after M. Heratsi, Yerevan, Armenia.

18 6. Foundation for Scientific Research of Suriname, Paramaribo, Suriname

19

20 ***Corresponding author:** e-tuailon@chu-montpellier.fr

21 Centre Hospitalier Universitaire de Montpellier, Laboratoire de Virologie Lapeyronie, 371 avenue du Doyen

22 Gaston Giraud, 34295 Montpellier Cedex 5, France. Tel : +33 4 67 33 83 40 Fax: +33 4 67 33 83 34

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35 **Abstract**

36 Blood spotted onto filter paper can be easily collected outside healthcare facilities and shipped to a
37 central laboratory for serological testing. However, dried blood testing generally requires manual
38 processing for pre-analytical steps. In this study, we used a standardized blood collection device
39 combined with an automated elution system to test illegal gold miners living in French Guiana for
40 human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV) and syphilis. We
41 included 378 participants, 102 females and 266 males, in three illegal gold mining resting sites. Blood
42 collected on the Ser-Col device (Labonovum) was eluted using an automated system (SCAUT Ser-Col
43 automation, Blok System Supply) and an automated analyzer (Alinity i, Abbott). Ser-Col results were
44 compared to both plasma results, considered the gold standard, and to Dried blood Spot DBS results,
45 considered the reference sampling method using dried blood. In plasma samples, two participants
46 (0.5%) tested positive for HIV, six (1.5%) tested positive for hepatitis B surface antigen (HBsAg), eight
47 were weakly positive for anti-HCV antibodies but negative for HCV RNA, and 47 tested positive for
48 treponemal antibodies (12.4%), including 20 females (19.6%) and 27 males (9.8%, $p= 0.010179$). We
49 observed a full concordance of Ser-Col and DBS results for HIV diagnosis compared to plasma results.
50 Ser-Col and DBS samples tested positive in five HBsAg carriers and negative for one participant with a
51 low HBsAg level in plasma (0.5 IU/mL). All participants tested negative for HCV in Ser-Col and DBS
52 samples, including the eight participants who tested low positive for HCV antibodies and HCV RNA
53 negative in plasma. Among syphilis seropositive participants, 41 (87.2%) and 40 (85.1%) tested positive
54 for treponemal antibodies in Ser-Col and DBS samples, respectively. The Ser-Col method allows
55 automated dried blood testing of HIV, HBV, HCV and syphilis with performances comparable to DBS.
56 Automated approaches to test capillary blood transported on dried blood devices may facilitate large-
57 scale surveys and improve testing of populations living in remote areas.

58

59

60 **Keywords:** HIV, hepatitis B, hepatitis C, syphilis, vulnerable population, Dried Blood Spot

61 **Introduction**

62 Reducing the burden of infectious diseases requires a global approach that includes underprivileged
63 people. To date, a significant part of the world's population has insufficient access to reliable infectious
64 disease diagnostic services. Migration, forced displacement of populations, weak infrastructure and
65 long distance from health services are common unfavorable health factors. A lack of in vitro diagnostic
66 tools contributes largely to the mortality and morbidity induced by infectious diseases in resource-
67 limited countries (Organization, 2013). A low number of laboratories and poor logistical infrastructure
68 are major problems in many of these countries. Laboratory equipment defined by World Health
69 Organization (WHO) as essential for basic service readiness is also insufficient (Leslie et al., 2017). The
70 weakness of human resources - health professionals and biologists - should also be noted (Kruk et al.,
71 2018).

72 Capillary blood sampling performed outside healthcare facilities is one strategy to improve the
73 screening of hard-to-reach and key populations. Dried blood spot (DBS) testing programs have been
74 implemented for several years, targeting intravenous drug users (McLeod et al., 2014), sex workers
75 (Shokoohi et al., 2016), homeless populations (Foroughi et al., 2017), migrants and men who have sex
76 with men (Bogowicz et al., 2016). Today, WHO considers DBS samples as a possible alternative to
77 serum/plasma to improve access to human immunodeficiency virus (HIV), hepatitis B virus (HBV) and
78 hepatitis C virus (HCV) screening and therapeutic monitoring. However, DBS testing has several
79 constraints, such as a lack of standardized blood sampling and elution procedures and the need to
80 manually process DBS cards, which have limited the use of DBS in clinical laboratories.

81 In French Guiana, about 10,000 illegal gold miners, mainly Brazilians (95%), work on more than 700
82 different mining sites located in the primary forest (Douine et al., 2017). This neglected population
83 experiences very poor access to Health (Douine et al., 2017). People working on gold panning sites are
84 particularly exposed to vector-borne diseases, including malaria (Douine et al., 2016) and leishmaniasis
85 (Douine et al., 2017). Our previous data also suggest a high prevalence of sexually transmitted

86 infections such as HIV (1.4% (95% CI: 0.29-2.56)), HBV (hepatitis B surface antigen (HBsAg): 4.6% (95%
87 CI: 2.6-6.6)) and syphilis (anti-treponemal antibodies: 11.5% (95% CI: 8.5-14.6), (Douine et al., 2019).
88 Transactional sex occurs frequently in gold mining sites (Douine et al., 2019; Gaillet et al., 2017).
89 According to a survey carried out in the city of Cayenne in French Guiana, it may contribute to 45% of
90 HIV cases in men and 10.7% in women (Nacher et al., 2010). In a study carried out on the gold sites of
91 French Guiana, about 10% of women declared having already engaged in sex work activity (Douine et
92 al., 2017).

93 In this study, we used an innovative blood collection device combined with an automated elution
94 system to test illegal gold miners living in French Guiana for HIV, HBV, HCV and syphilis.

95 **Material and Methods**

96 Study design

97 This cross sectional study is part of the EU-funded “SCAUT” research project (from finger to laboratory:
98 personalized and automated blood collection for laboratory diagnostics). The SCAUT study allowed to
99 develop Ser-Col device and to evaluated it on the analytical and clinical validation.

100 Participants were adults working in illegal gold mining sites in French Guiana regardless of the nature
101 of their activity, - seller, cook, gold miner -, and included in the Malakit study. The Malakit study aimed
102 to evaluate an innovative malaria control strategy amongst gold miners working illegally in French
103 Guiana by offering a kit for self-diagnosis and self-treatment. Participants were sampled by snow-ball
104 effect at the staging areas with a progressive roll-out in the inclusion sites located at staging areas for
105 gold miners. The methodology has been previously published (Lambert et al., 2022)(for further details
106 see www.malakit-project.org). Due to resource constraints, we included in the SCAUT study 10% of the
107 participants of the Malakit study (3.733 participants). Participants were included after having provided
108 informed written consent. All participants had left a mining site less than seven days prior to being
109 tested. Samples collected from 1st October to 16th November 2019 were sent from the resting site to
110 the hospital center of Cayenne and then to the Montpellier University Hospital to be tested. Results

111 from plasma samples were communicated to collection sites within two weeks on each site during the
112 post-test counseling. Paired samples of Ser-Col and DBS were tested in parallel for the SCAUT study.
113 The study obtained approval from ethical committee in France: INSERM Ethics Evaluation Committee
114 (No. 14-187 of 09.12.2014), in Suriname: CMWO. Approval No: VG 25-17; ClinicalTrials.gov identifier
115 (NCT number: NCT03695770).

116 Objectives and evaluation criteria

117 Our first objective was to evaluate the performance of combined HIV, HBV, HCV, and syphilis testing
118 using an innovative blood collecting device compared to serum and DBS samples. Sensitivity and
119 specificity of the tests performed on the Ser-Col device and DBS were calculated based on results of
120 the gold standard (serum).

121 Secondary objective was to assess the prevalence of the specified infections among illegal gold miners.

122

123 Sample collection and processing

124 Blood samples were collected in three out of five resting sites of the Malakit study located along the
125 border between French Guyana and Suriname, on the Maroni river: Albina, Grand Santi and
126 Maripasoula (Fig. 1).

127 For routine laboratory methods blood were collected in a 5 ml ethylene diamine tetraacetic acid tube
128 for testing of HIV, HBV, HCV and syphilis. Tubes were centrifuged in the 24h after collection and send
129 at 4°C to the Cayenne Hospital where plasma were stored at -80°C. The plasma samples were sent
130 afterwards to the Montpellier University Hospital.

131 Serological analysis (HIV p24/antibodies, HBsAg, anti-HCV antibodies, and anti-treponemal antibodies)
132 were done using fully automated chemiluminescence immunoassays (Alinity i, Abbott, IL, USA).
133 According to the manufacturer, the threshold >1 was considered as positive result for HIV, HBsAg, anti-
134 HCV antibodies and anti-treponemal antibodies analysis. Plasma that tested positive for HIV were

135 confirmed using a rapid confirmatory assay based on immune-chromatography and automated
136 reading (Geenius™ HIV1/2 Confirmatory Assay, Bio-Rad, France). Plasma samples positive for HCV
137 antibodies were tested for HCV viral RNA (Alinity m, Abbott, IL, USA). Plasma samples positive for anti-
138 treponemal antibodies were tested by Rapid Plasma Reagin Assays (ASI RPR, Arlington Scientific Inc.).
139 All assays were done in accordance with the manufacturer's instructions.

140 To test the performance of serological assays performed on the new blood collection device, blood
141 was spotted onto the Ser-Col device (Labonovum, Netherlands). Blood was also spotted onto a filter
142 paper card (Whatman 903; GE Healthcare Europe, Freiburg, Germany), for comparison. The Ser-Col
143 device and filter paper card were dried at ambient temperature, transported at 4 °C and stored at
144 – 80°C until used. The processing of blood collected on the Ser-Col device was performed using an
145 automated system (SCAUT Ser-Col automation, Blok System Supply, Netherlands). The Ser-Col device
146 contains a microfluidic paper separating plasma from whole blood. The automated system performed
147 the elution from dried plasma contained in one centimeter of paper in 100µL of Ser-Col buffer. Elution
148 of blood spotted DBS were manual. One punch of 6 mm in diameter was eluted in 100µL of phosphate-
149 buffered saline. Ser-Col device eluates and DBS eluates were tested using the Alinity i immunoassays
150 according to the manufacturer instructions for plasma, except for anti-treponemal antibodies for
151 whom analysis, the threshold was reduced to 0.28 S/CO for Ser-Col device and DBS.

152

153 Data analysis and statistical methods

154 Ser-Col results were compared to plasma results, considered the gold standard for diagnostic testing
155 in general, and to DBS results, considered the reference sampling method using dried blood. The Chi-
156 square test was used to compare percentages. Receiver operating characteristic curves (ROCs) were
157 used to identify the positive threshold of anti-treponemal antibodies in Ser-Col and DBS. Spearman's
158 non-parametric test was used to assess the correlation between results of anti-treponemal antibodies

159 in Ser-Col and DBS, versus plasma. Data results were analyzed using GraphPad Prism 9.3.1 (GraphPad
160 Prism Software Inc.).

161 **Results**

162 We included 378 participants, 276 males and 102 females, in three illegal gold mining resting sites. The
163 median (IQR) age of the participants was 39 years (31-48).

164 We first tested participants for HIV, HBV, HCV and syphilis infections using plasma to determine their
165 infection status for these infections (Fig.2-3 and Table 1). Two participants tested positive for HIV
166 (0.53%). HIV infection was confirmed. The pattern of antibodies showed IgG directed against gp160,
167 gp41, p24 and p31 (low signal) of HIV-1 for the first participant, and gp160, gp41, and p24 with no p31
168 antibodies for the second one. We did not observe any reactivity for HIV-2 antigens (gp140, gp36). Six
169 participants (1.59%) had HBV infection demonstrated by the presence of HBsAg. One participant had
170 a weakly positive result with a signal-to-cut-off ratio (S/CO) of less than 10, corresponding to an HBsAg
171 concentration of 0.5 IU/mL. Eight participants (2.12%) tested positive for anti-HCV antibodies, but all
172 had index values close to the threshold of positivity. In addition, all of them tested negative for HCV
173 RNA, suggesting a recovered hepatitis C infection or a false-positive result. Forty-seven participants
174 (12.43%) tested positive for syphilis using the treponemal test, (S/CO: 1.03 to 19.59). The proportion
175 of positivity for treponemal antibodies was higher in females than in males: 20/102 (19.6%) versus
176 27/276 (9.8%, $p = 0.01$), respectively (Fig.4A). Among participants who tested positive for treponemal
177 antibodies, 13/47 (27.6%) also tested positive using the non-treponemal test, suggesting an active
178 stage of infection or a recently treated infection (3 females, 10 males). RPR dilution titers were 1:2 for
179 five participants, 1:4 for six, 1:8 for one, and 1:32 for one.

180 The Ser-Col samples then were tested for HIV, HBV, HCV and syphilis after automated elution. The
181 eluates were assessed directly on the Abbott system without transfer into a secondary tube. All of the
182 Ser-Col samples from HIV-seronegative participants tested negative, leading to a specificity of 100%.
183 Two participants (0.53%) diagnosed with HIV infection were found positive using the Ser-Col device.

184 (Fig.3A). The HIV confirmatory test was positive in the two samples. We observed a partial agreement
185 between Ser-Col and plasma in one sample in whom the p31 band was detected in plasma but not in
186 Ser-Col eluate (Table 1). Five of the six HBsAg carriers tested positive (1.32%) when using the Ser-Col
187 device (Fig.3B). The Ser-Col sample with the lowest HBsAg concentration in the paired plasma sample
188 (0.5 IU/mL) tested negative. Two Ser-Col samples from HBsAg negative participants (0.53%) had signals
189 above the cut-off and were considered false-positive. The S/CO were close to the positive threshold.
190 All HCV seronegative participants were also found negative for anti-HCV antibodies using the Ser-Col
191 device (Fig.3C). The eight participants with the HCV Abs +/RNA- pattern were found negative using the
192 Ser-Col device. All Ser-Col samples from participants seronegative for anti-treponemal antibodies in
193 plasma tested negative. 20 out of 47 (42.5%) participants who tested positive for anti-treponemal
194 antibodies in plasma had S/CO results below the threshold of the manufacturer. The signal on the cut-
195 off index was significantly higher in participants who tested positive for anti-treponemal antibodies in
196 the plasma. We established an optimized positive threshold based on a ROC curve. The best
197 compromise was reached with an S/CO threshold of 0.28 instead of 1, corresponding to a sensitivity
198 and a specificity of 74.6% and 98.4%, respectively. The area under the curve (AUC) was 95.17 with this
199 new threshold (Fig.4B).

200

201 Finally, DBS samples were tested for HIV, HBV, HCV and syphilis. We observed identical screening
202 results for HIV using DBS compared to plasma samples (Fig.3A). The p31 band bands were also missing
203 on the DBS samples of the first and second HIV positive participants (Table 1). As for the Ser-Col
204 samples, the sample with the lowest HBsAg concentration tested negative using DBS. Two DBS samples
205 collected from HBsAg negative participants had an S/CO above the positive threshold (Fig.3B). These
206 samples were not the same as those found false-positive using the Ser-Col samples. 23 out of 47
207 (48.9%) participants who tested positive for anti-treponemal antibodies in plasma had S/CO results
208 below the threshold of the manufacturer. The ROC curve for the screening of anti-syphilis antibodies

209 led to an AUC of 95.25, with a sensitivity and a specificity of 73.9% and 98.1%, respectively, with a
210 threshold of 0.28 (Fig.4C).

211 **Discussion**

212 Our study shows the feasibility of serological screening for sexually transmitted infections in a
213 vulnerable population living in a remote area using a standardized dried blood device and a fully
214 automated processing system. The clinical performance of the assays using the Ser-Col device
215 appeared as good as those using DBS while overcoming some of the limitations related to DBS
216 processing. This approach allows combined screening for HIV, HCV, HBV and syphilis infections on
217 blood collected outside health care facilities in gold mining resting sites.

218 Prevalence for HIV (0.5%), HBV (1.6%) and syphilis (12.4%), observed in our study are consistent with
219 results that we previously reported in this population (Douine et al., 2019), namely 1.4% for HIV, 4.6%
220 for HBV, and 11.5% for syphilis. With the exception of syphilis, the number of positive cases was
221 relatively low, which leads to imprecise estimates of prevalence. These figures are close to HIV, HBV
222 and HCV prevalence estimations in French Guiana. The prevalence of HIV has been estimated at 1.5%
223 (Nacher et al., 2018), at 2.96% for HBV and 0.67% for HCV infection (Moana et al., 2016).

224 In remote areas and among vulnerable populations, some people living with HIV and viral hepatitis are
225 unaware of their infection status (Organization, 2016). It is of primary importance to increase the
226 frequency of screening for HIV, HBV and HCV infections. Capillary blood sampling and dried blood
227 transportation could facilitate large-scale health surveys. This type of population testing has been
228 carried out using DBS, for example for viral hepatitis (Meda et al., 2018) and SARS-CoV-2 (Warszawski
229 et al., 2022).

230 This field study was carried out on difficult terrain. The population of illegal gold miners in French
231 Guiana consists of migrants living far from transport networks and health infrastructure in a harsh
232 tropical environment. In this study, sampling was done close to the field and in vitro diagnoses were
233 performed in a central laboratory certified ISO 15189 for HIV, HBV, HCV and syphilis testing using a

234 high-throughput serological platform. The transportation of samples from the field to a central
235 laboratory is facilitated when using dried blood because there is no risk of the biological fluid spilling
236 and no risk of virus transmission. Serological and molecular tests on DBS have shown satisfactory
237 analytical performance for HIV and viral hepatitis (Lange et al., 2017a; Lange et al., 2017b). DBS is
238 recommended by WHO for the diagnosis of HIV and viral hepatitis B and C to improve access to in vitro
239 diagnosis of populations with poor access to plasma tests (Organization, 2017; World Health et al.,
240 2014). Nevertheless, DBS suffers from significant limitations that hamper its use, including the lack of
241 standardization of the sample and the absence of automation for the pre-analytical steps: punching,
242 transfer and elution. The manual processing of DBS is a source of error and limits its integration in
243 medical laboratories. The Ser-Col device and its automated processing overcome these limitations.

244 In our study, the screening on Ser-Col samples presented a high specificity, identifying HIV and HBV
245 infections with the exception of one weakly HBsAg-positive sample. Two Ser-Col samples were false-
246 positive for HBsAg but with low S/CO values. The specificity for HCV also appeared high but the
247 sensitivity could not be calculated since all participants tested seronegative for HCV RNA. The
248 performance of the syphilis assay is more uncertain since about a quarter of the low plasma positive
249 participants were not detected when using the Ser-Col device. These participants had relatively weak
250 positive results in plasma, suggesting an old, cured syphilis. However, a very recent infection would
251 also be possible. Performance for syphilis screening was similar using the Ser-Col device and DBS. Even
252 if the performance of screening for anti-treponemal antibodies on Ser-Col or DBS is lower than that of
253 plasma, this method of blood sampling could be useful for syphilis testing in the field. A trade-off
254 between the analytical performances of the test and its accessibility in the field should be considered
255 to evaluate the benefit of in vitro diagnosis methods in the real world, as emphasized in the WHO
256 guidelines (Organization, 2017; World Health et al., 2014). The Ser-Col device allows an automated
257 elution and the standardization of the pre-analytical steps which offers substantial advantages
258 compared to DBS. However, the Ser-Col device and SCAUT automate have some limits: the cost of the

259 Ser-Col is approximately twofold higher compared to Whatman 903 card and the automation requires
260 a dedicated machine and laboratory facilities.

261 Our study has several limitations. First, we did not evaluate loss of follow-up before participants
262 obtained the results. This is an important aspect of screening strategies. Compared to POC tests,
263 laboratory analyses, whether carried out on plasma or dried blood samples, entail a longer delay
264 before the result is returned, and therefore a greater risk of patient loss to follow-up before the test
265 results are given to the patient (Bottero et al., 2015). Another limitation is the low number of positive
266 participants for HIV, HBV and HCV infections even though a large number of participants were tested.
267 Finally, we only performed qualitative tests, whereas quantitative results may be interesting for the
268 diagnosis of infectious diseases. The antibodies HBs are not tested to identify the characteristic of HBV
269 infection status. HCV viral RNA was tested only in participants with a positive HCV serology result. So,
270 it's possible to do not identify potential positive participants to the HCV viral RNA.

271 **In conclusion**, the Ser-Col device combined with automated elution allows the standardization and
272 safety of the pre-analytical steps of analysis performed on dried blood samples. The clinical
273 performances of the assays using the automated Ser-Col method appeared as good as those obtained
274 with the DBS samples processed manually. Automated approaches to test capillary blood transported
275 on dried blood devices are needed to enable testing of vulnerable populations living outside healthcare
276 facilities and facilitate large-scale surveys assessing the burden of different infectious pathogens.

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286 **Declarations**

287 Ethics approval and consent to participate

288 The study obtained approval from ethical committee in France: INSERM Ethics Evaluation Committee
289 (No. 14-187 of 09.12.2014), in Suriname: CMWO. Approval No: VG 25-17; ClinicalTrials.gov
290 identifier (NCT number: NCT03695770).

291 Competing interests

292 DP, RM and JL are Labonovum employees.

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294 This study is part of the EU-funded “SCAUT” research project (from finger to laboratory: personalized
295 and automated blood collection for laboratory diagnostics).

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298 CRediT authorship contribution statement

299 **Amandine PISONI** : Conceptualization, Methodology, Validation, Formal analysis, Writing - Original
300 Draft ; **Elisa REYNAUD** : Validation ; **Maylis DOUINE** : Investigation ; **Louise HUREAU** : Investigation ;
301 **Carmen ALCOCER CORDELLAT** : Investigation ; **Roxane SCHAUB** : Investigation ; **Dennis POLAND** :
302 Conceptualization and Methodology ; Funding acquisition ; **Richard MONKEL** : Investigation :
303 Resources ; **Joan LOMMEN** : Investigation ; **Konstantin YENKOYAN** : Conceptualization and
304 Methodology ; Funding acquisition ; **Stephen VREDEN** : Writing - Review & Editing ; **Mathieu NACHER** :
305 Investigation, Resources ; **Edouard TUAILLON** : Conceptualization and Methodology; Formal analysis:
306 Resources ; Writing - Original Draft; Funding acquisition ; **All authors** : Writing - Review & Editing

307

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387

Figure 1.

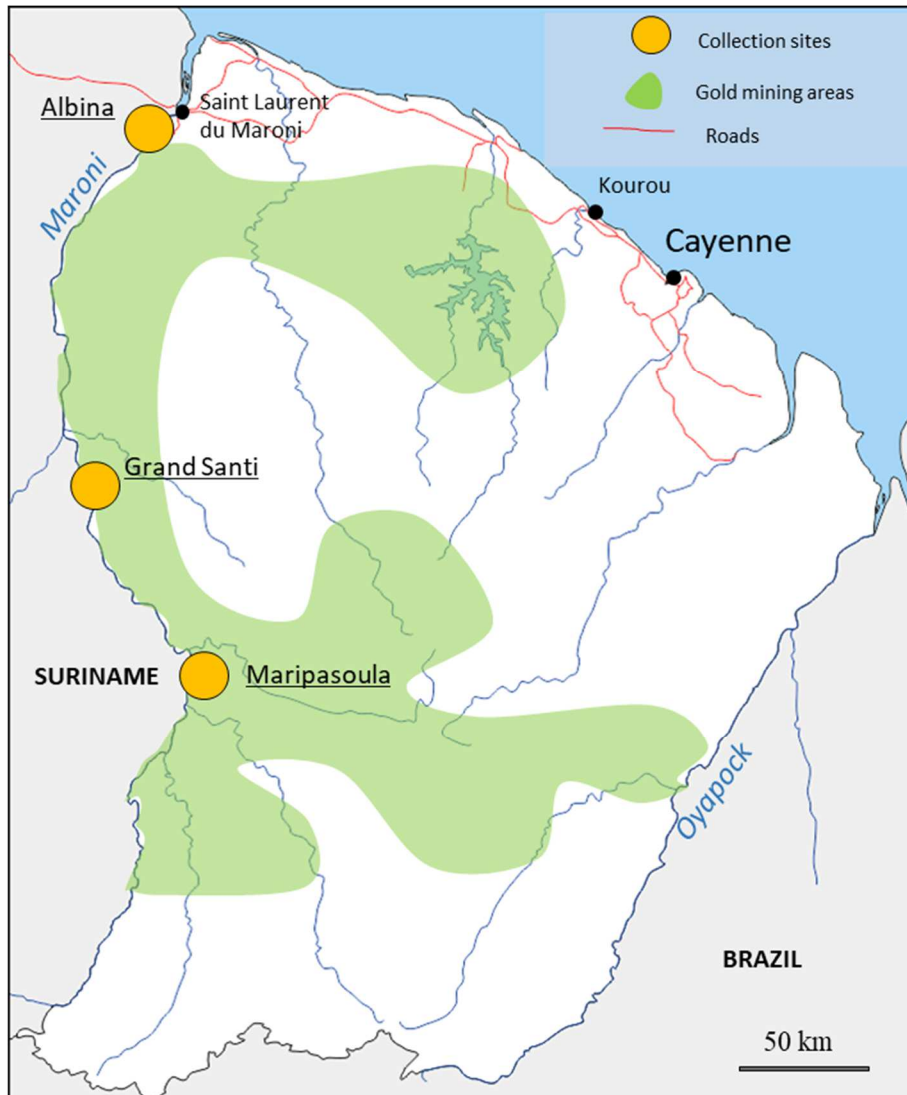


Figure 1. Sampling location of the Orpal study in French Guiana. Green area indicates illegal gold mining sites. Orange circles on the Maroni river indicate collection sites that were located in resting places.

Figure 2.

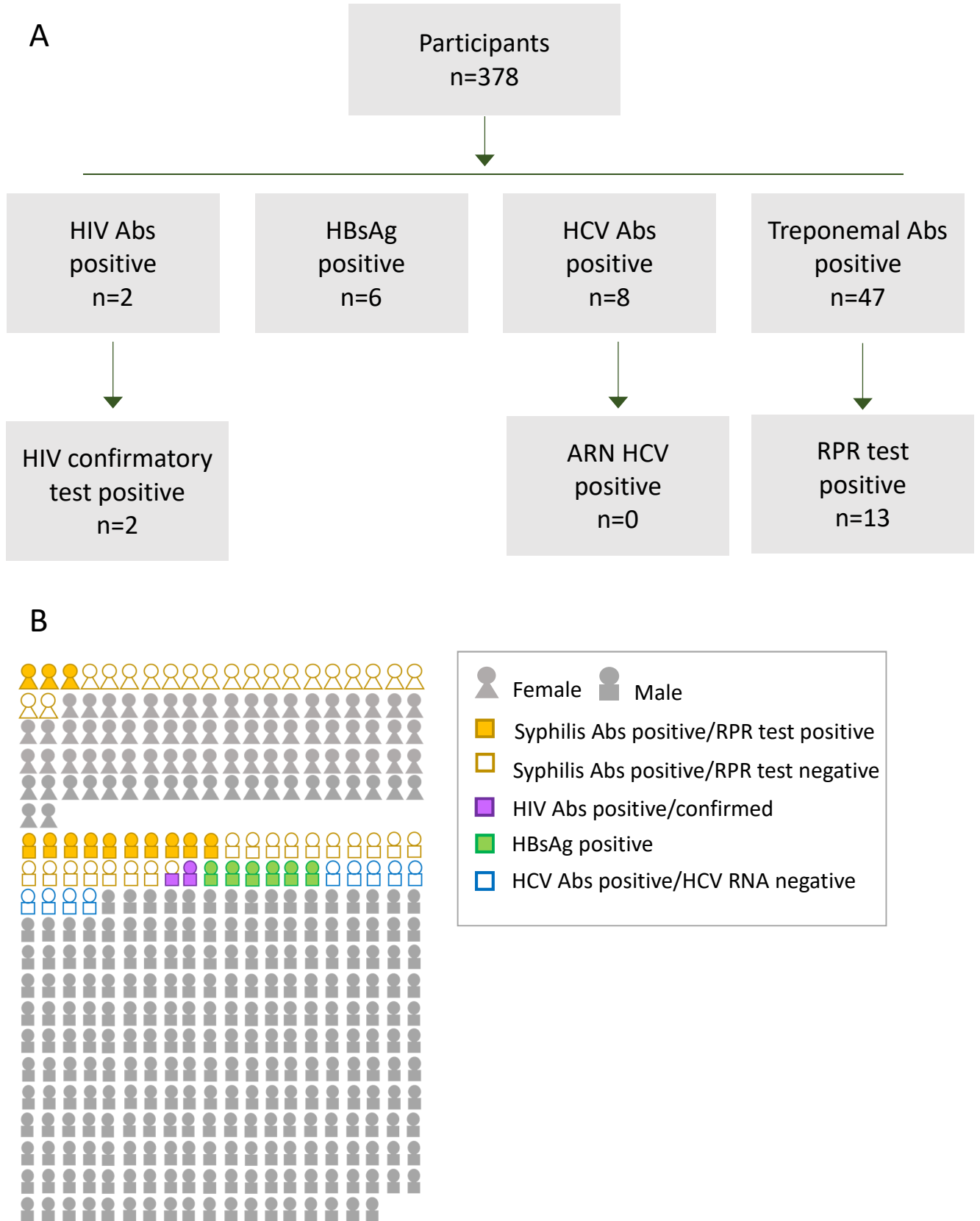


Figure 2. Screening of infections in illegal gold miners in French Guyana. A) Results for HIV, hepatitis B, hepatitis C, and syphilis in plasma samples HBsAg: hepatitis B surface antigen; Abs: antibodies; RPR: rapid plasma reagin test. B) Individual results.

Figure 3.

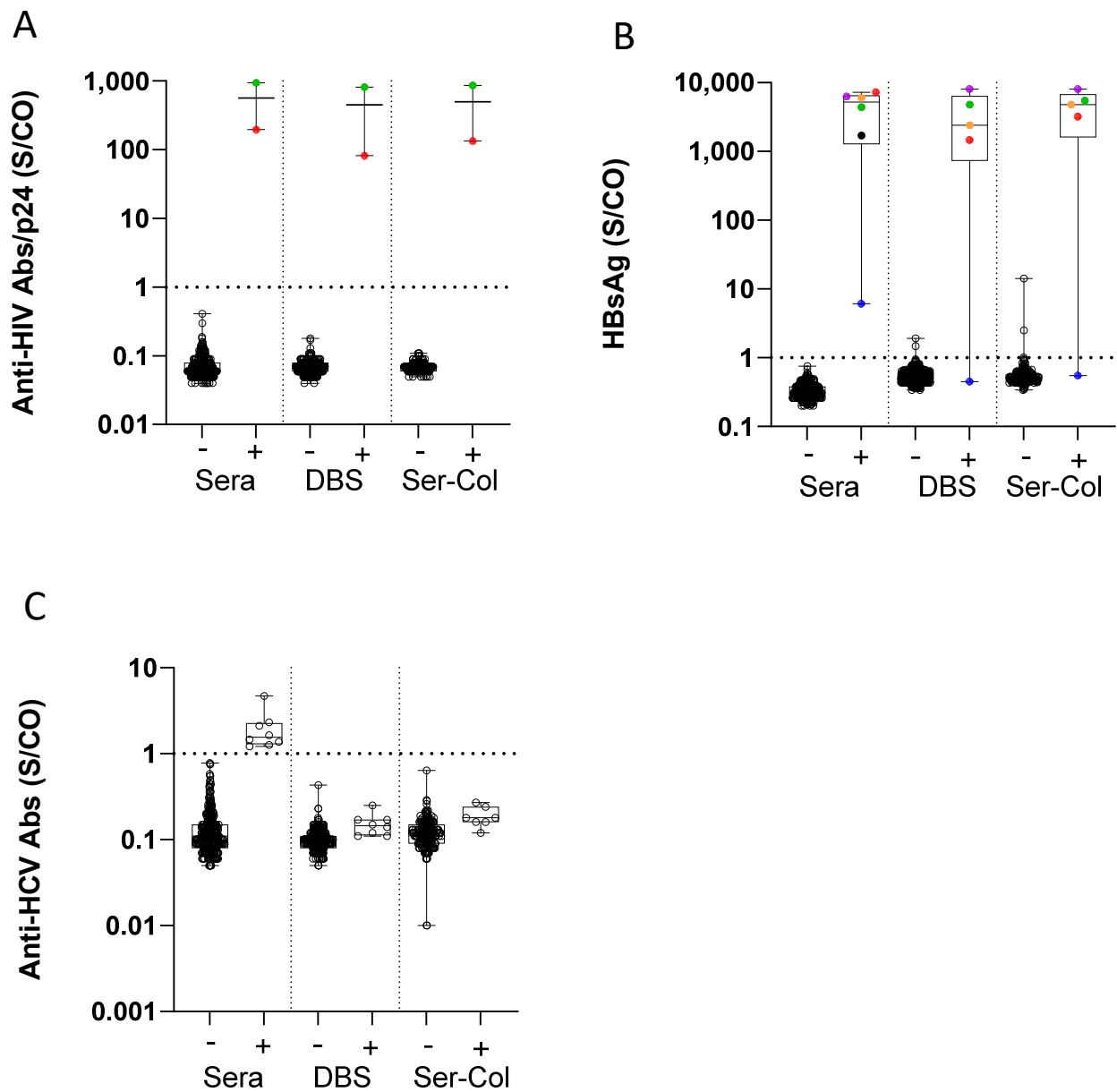
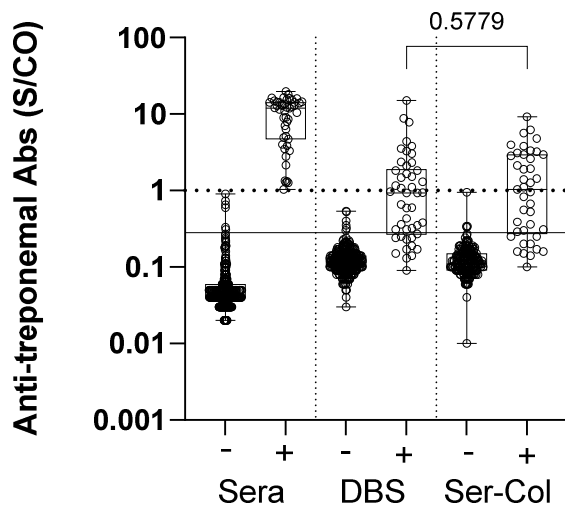


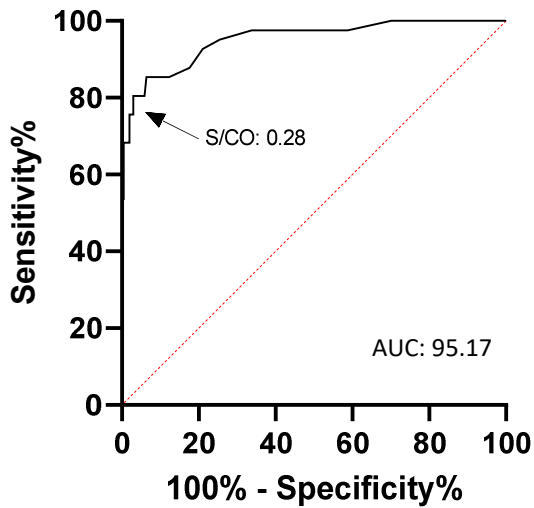
Figure 3. Results of HIV, hepatitis B and hepatitis C testing on Ser-Col and DBS samples. A) Results of HIV testing in Ser-Col samples and dried blood spot (DBS) according to HIV status in sera. B) Results of HBsAg testing in Ser-Col samples and dried blood spot (DBS) according to HBsAg status in sera. C) Results of hepatitis C antibody testing in Ser-Col samples and dried blood spot (DBS) according to anti-HCV status in sera. All samples tested positive for anti-HCV Abs were negative for HCV RNA.

Figure 4.

A



B



C

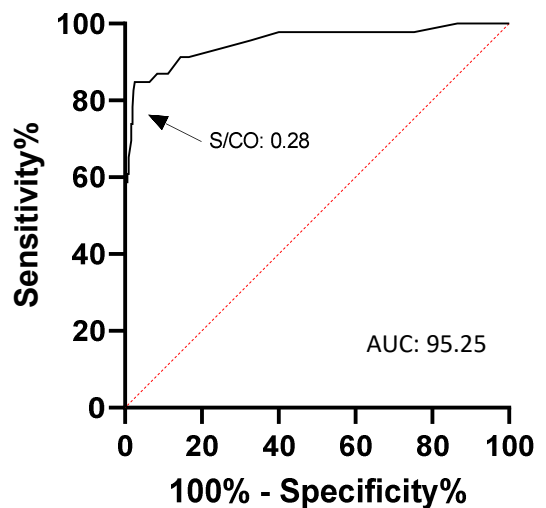


Figure 4. Anti-treponemal antibody results in Ser-Col and Dried Blood Spot samples. A) Anti-treponemal antibodies in Ser-Col samples and dried blood spot (DBS) according to syphilis serological status in plasma; dotted line: threshold of the manufacturer; solid line: optimized threshold for Ser-Col and DBS samples. B) Receiver operating characteristic curve (ROC) evaluating anti-treponemal antibody detection in Ser-Col samples. C) ROC evaluating anti-treponemal antibody detection in DBS samples.

Table 1. Serological results using plasma, Ser-Col, and DBS samples

	Plasma (n=378)		Ser-Col (n=378)			DBS (n=378)		
	Negative	Positive	Negative	Positive	p-value	Negative	Positive	p-value
HIV								
HIV-Abs/p24 Ag Confirmatory assay ^h	376	2 gp160+, gp41+, p31+, p24+ gp160+, gp41+, p31-, p24+	376	2 gp160+, gp41+, p31-, p24+ gp160+, gp41+, p31-, p24+	p=1	376	2 HIV-1: gp160+, gp41+, p31-, p24+ HIV-1: gp160+, gp41+, p31-, p24+	p=1
Hepatitis B								
HBsAg	372	6	373	5	p=0.7613	373	5	p=7613
Hepatitis C								
HCV Abs	370	8	378	0	p=0.0045	378	0	p=0.0045
HCV RNA ^h	8	0	ND	ND		ND	ND	
Syphilis								
Treponemal Abs	331	47	337	41	p=0.2335	338	40	p=0.1959
Non-treponemal test ^h	34	13						
1:2		5	ND	ND		ND	ND	
1:4		6	ND	ND		ND	ND	
1:8		1	ND	ND		ND	ND	
1:32		1	ND	ND		ND	ND	

DBS: Dried blood spot ; Abs : antibodies ; Ag : antigen ; HBsAg : Hepatitis B surface antigen ; ND : not done. ^h among seropositive samples

Graphical abstract

Automated and combined HIV, HBV, HCV, and syphilis testing among illegal gold miners in French Guiana using a standardized dried blood device

