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## Development and internal validation of a diagnostic score for gastric linitis plastica

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### ► To cite this version:

J. Vivier-Chicoteau, J. Lambert, R. Coriat, P. E Bonnot, D. Goéré, et al.. Development and internal validation of a diagnostic score for gastric linitis plastica. *Gastric Cancer*, In press, 10.1007/s10120-020-01051-x . hal-02555520

**HAL Id: hal-02555520**

**<https://u-paris.hal.science/hal-02555520v1>**

Submitted on 27 Apr 2020

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## ORIGINAL ARTICLE

### TITLE:

Development and internal validation of a diagnostic score for gastric linitis plastica

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### SHORT RUNNING HEAD:

Diagnostic score for linitis plastica

**THE WORD COUNT OF THE ARTICLE: 3310**

1 **ABSTRACT:**

2 **Background:**

3 There is no consensual definition for gastric linitis plastica (GLP). We aim to construct a  
4 diagnostic score to distinguish this rare tumor from usual gastric adenocarcinomas.

5 **Methods:**

6 In this retrospective study, all patients who had gastrectomy for cancer between 2007 and  
7 2017 in French tertiary centers were included. The outcome was a diagnosis of GLP based on  
8 pathological review of the surgical specimen. The diagnostic score was created by using  
9 variables that were most frequently associated with GLP using penalized logistic regression  
10 on multiply imputed datasets. We used discrimination measures to assess the performances  
11 of the score. Internal validation was performed using bootstrapping methods to correct for  
12 overoptimism.

13 **Results:**

14 220 patients including 71 linitis plastica (female 49%, median age 57 years) were analyzed.  
15 The six parameters retained in the diagnosis score were the presence of large folds and/or  
16 parietal thickening on at least one segment, pangastric infiltration and presence of gastric  
17 stenosis on the upper endoscopy, circumferential thickening on at least one segment and  
18 thickening of the third hyperechogenic layer on endoscopic ultrasound and the presence of  
19 signet ring cells on endoscopic biopsies. The area under the ROC curve (AUC) was 0.967 with  
20 a sensitivity of 94% [89.9-97.3] and a specificity of 88.7% [81.7-95.8] for a threshold of 2.75.  
21 After internal validation, the corrected AUC was 0.959.

22 **Conclusion:**

23 It's the first study validating a pre-therapeutic diagnostic score (Saint-Louis linitis score) with  
24 an excellent ability to discriminate GLP from non-GLP adenocarcinomas. An external  
25 validation is necessary to confirm our data.

26

27 **KEYWORDS:**

28 Linitis plastica

29 Diagnostic score

30 Gastrectomy

31 **INTRODUCTION:**

32 Gastric adenocarcinoma (GA) is the fifth most common cancer in the world (1). Despite  
33 medico-surgical progress, its prognosis remains poor, ranking third among the most fatal  
34 cancers (1,2). There are various classifications of GA, either purely histological (3–5), or  
35 taking into account the macroscopic aspect (6), or the site of the tumor (7). Among the  
36 different subtypes, gastric linitis plastica (GLP) represents a particular entity. It develops  
37 from the submucosa and is characterized macroscopically by a major segmental or diffuse  
38 thickening of the gastric wall and microscopically by the existence of poorly cohesive and/or  
39 signet ring cells, within an abundant fibrous stroma infiltrating all the tunics (8,9). The terms  
40 of poorly cohesive and/or signet ring cell carcinoma (SRC) and GLP are often indiscriminately  
41 used leading to confusion in literature and difficulties to define the best therapeutic options  
42 for this subtype of gastric tumor. GLP appears to have specific characteristics such as  
43 younger age at diagnosis, female predominance, increased frequency of stages 3 and 4 and  
44 lymph node invasion, and significantly decreased overall survival due to higher frequency of  
45 R1 resection (10,11). Despite these specific features, there is to date no clear definition of  
46 GLP. A recent consensus on the pathological definition and classification of poorly cohesive  
47 gastric carcinoma propose that GA should be classified according to the WHO classification;  
48 the term GLP being reserved for the description of the macroscopic characteristics of the  
49 tumor (12). According to those discrepancies, the gold standard for GLP diagnosis is  
50 currently based on histological examination of a surgical specimen (13,14). However in case  
51 of locally advanced or metastatic disease which represents the vast majority of the patients,  
52 surgery is rarely done. Thus, the diagnosis of GLP is mainly based on a simple set of  
53 arguments (clinical, endoscopic, scannographic, histological). In case of a planned surgery for  
54 localized GLP, the impact of preoperative chemotherapy remains uncertain and a total

55 gastrectomy is needed even in case of peroperative impression of free margin. The  
56 development of a new diagnostic tool in order to make an early diagnosis of GLP remains  
57 challenging and may lead to better understanding and significant therapeutic advances in  
58 this field. The aim of this study is to construct a diagnostic score to discriminate GLP from  
59 others GA.

60 **METHODS:**

61 All patients who underwent a gastrectomy for gastric cancer between 2007 and 2017 in  
62 seven French tertiary centers were retrospectively identified either from a hospital database  
63 known as Programme de Médicalisation des Systèmes d'Information (PMSI) or from  
64 databases of the Gastroenterology departments. All the the files were reviewed by the same  
65 person (JVC) to minimize missing data and control concordance; collected data included  
66 information concerning demographic characteristics, case history, biological parameters,  
67 description of endoscopic, endoscopic ultrasound and computed tomography scan findings,  
68 type of surgery, histological analysis of surgical specimen and the treatments used.

69 Exclusion criteria were: genetic gastric cancer, history of gastric surgery for any reason,  
70 history of endoscopic resection for superficial tumor prior to surgery (endoscopic mucosal  
71 resection or submucosal dissection), gastro-esophageal junction cancer, non-  
72 adenocarcinomatous gastric tumor, adenocarcinoma infiltration of extra-gastric origin and  
73 absence of tumor residue on the pathology report. We also excluded the files with at least  
74 one major missing data (histological report of endoscopic biopsies or surgical specimen,  
75 digestive endoscopy report). The large number of excluded patients is due to the  
76 retrospective design of our study and the lack of computerization of medical data in some  
77 centers (incomplete paper records). and non-available histological report. Patients were  
78 treated in accordance with the Helsinki Declaration (World Medical Association Declaration  
79 of Helsinki. Ethical principles for medical research involving human subjects. *Bulletin of the*  
80 *World Health Organization*, 2001, 79 (4), 373 - 374). All data were anonymously collected  
81 and, according to the Loi Jardé (French law amended by Order No. 2016-800 and its  
82 implementing decree No. 2016-1537 of 16/11/ 2016 relating to research involving the

83 human person), no patient consent was needed, as the treatment implemented in this study  
84 was the standard recommended therapy.

85 To create the score, our study population was divided into 2 groups: GLP group and non-  
86 linitic adenocarcinoma (non-GLP or control group).

### 87 **Definition of GLP and pathological analysis**

88 The diagnosis of GLP was retained if the three following criteria were mentioned on the  
89 pathology report of surgical specimen:

- 90 - Macroscopic examination of the surgical specimen showing segmental or pangastric  
91 diffuse parietal thickening.
- 92 - Histological examination showing an abundant and diffuse fibrous stromal reaction  
93 extended throughout the gastric lining to the sub serosa.
- 94 - Histological examination showing a carcinoma with more than 50% poorly cohesive  
95 cells having classical SRC morphology.

96

97 The pathology reports of gastrectomy were all reviewed for validation by an expert  
98 pathologist in the reference center of Assistance Publique des Hôpitaux de Paris (APHP) for  
99 the treatment of oeso-gastric tumors. In some doubtful cases, a re-reading of the glass slides  
100 was carried out. If one of the 3 criteria was absent, the patient was excluded from the GLP  
101 group even if the clinical presentation and the morphological assessment appeared  
102 compatible with the diagnosis.

103 Patients in the non GLP group were randomly selected from the same centers without  
104 matching regardless of the presence or not of signet ring cells on surgical specimen.

105 All pathology reports of gastrectomy have been standardized according to the latest UICC  
106 AJCC 2016 classification (15).



107 **Parameters for diagnostic score**

108 The parameters taken into account for the creation of the score were demographic  
109 characteristics, symptoms at the diagnosis of GA, description of the initial upper  
110 gastrointestinal endoscopy and if available of gastric endoscopic ultrasound, description of  
111 pre-therapeutic abdominal computed tomography scan and histological description of  
112 endoscopic biopsies at diagnosis (cf Table 1 and 2). The biological parameters included for  
113 the creation of the score were: total blood count (anemia, increased neutrophils count,  
114 thrombocytosis), high neutrophil-to-lymphocyte ratio, elevated C-reactive protein,  
115 hypoalbuminemia, increased tumor markers (carcinoembryonic antigen, carbohydrate  
116 antigen 19-9). Further details are provided in Supplementary Tables 1-5.

117 **Statistical analysis**

118 Patient characteristics are presented using medians and interquartile ranges for quantitative  
119 data and counts with percentages for qualitative data. Characteristics of patients with and  
120 without GLP were compared using Wilcoxon tests for quantitative data and Chi2 tests or  
121 Fisher tests for qualitative data.

122 There were 12.6% of missing data among all the predictors considered, and only 5 % of  
123 patients had no missing data. Under the hypothesis of missingness at random, we used  
124 multiple imputations by chained equations to generate 20 imputed datasets. The diagnostic  
125 score was constructed with the most frequently selected predictors on these 20 datasets. To  
126 take into account for both the low variable/individual ratio with 71 patients having GLP and  
127 49 candidate covariates and the high risks of collinearities between candidate covariates, we  
128 used a generalized linear model with LASSO regularization (with 10-fold cross validation to  
129 select  $\lambda$  parameter) to build the multivariable model and select predictors. Finally, due to the  
130 near separation of some variables (no individuals in any of the modalities), a Firth penalized

131 logistic regression was performed to assess the respective importance of each predictor. The  
132 Firth logistic model was applied to each of 20 imputed datasets and the resulting mean value  
133 of each coefficient was used to construct the score. We rounded the coefficient to obtain an  
134 easy to calculate diagnostic score.

135 Performances of this score were assessed through discrimination measures: ROC curve, Area  
136 under the Curve (AUC), sensitivity and specificity at chosen threshold.

137 Finally, bootstrap resampling (200 bootstrap resampling for each of the 20 imputed  
138 datasets) allowed us to obtain an internal validation to correct for over-optimism in the  
139 discrimination measures. All statistical analyses were performed using R software

140 The methodology used is in agreement with the criteria defined by the TRIPOD checklist.

141 Further details are provided in Supplementary Table S6.

142 **RESULTS:**

143 **Patients' characteristics**

144 The files of 457 patients aged over 18 years who underwent a gastrectomy for gastric cancer  
145 were reviewed. Among them, 72 records were not analyzable due to major missing data. In  
146 the remaining 385 patients, 165 presented an exclusion criteria. Therefore, a total of 220  
147 patients (71 in the GLP group and 149 in the control group) met the inclusion criteria and  
148 were included in the analysis (Figure 1).

149 The general characteristics of the study population at diagnosis are presented in Table 1.  
150 Several statistical differences regarding epidemiological data and clinical presentation at  
151 diagnosis were noted between GLP and non-GLP patients. In the GLP group, the population  
152 was younger ( $p < 0.001$ ) with a higher proportion of women ( $p = 0.007$ ), a longer diagnostic  
153 time ( $p=0.02$ ) and the need to repeat iterative biopsy endoscopy more frequently ( $p <$   
154  $0.001$ ). Clinical presentation also differed with a higher proportion of patients with general  
155 impairment ( $p < 0.001$ ), undernutrition ( $p = 0.002$ ), dysphagia ( $p < 0.001$ ) and epigastralgia  
156 ( $p = 0.01$ ). In the non-GLP group, we noted a higher proportion of patients explored for  
157 anemia or with externalized digestive hemorrhage ( $p = 0.03$ ). Upfront surgery was  
158 performed in 4 patients in the GLP group (surgical decision at baseline:  $n = 3$ , perforation:  $n$   
159  $= 1$ ) and one patient in the non-GLP group (perforation).

160 The description of the main additional examinations carried out for diagnostic purposes is  
161 presented in Table 2.

162 **Endoscopic findings**

163 Several statistical differences were noted at endoscopic examination between GLP and non-  
164 GLP patients. In the GLP group, more patients with large folds or macroscopic tumor  
165 infiltration on at least one segment ( $p < 0.001$ ) with a higher frequency of multiple

166 ulcerations or erosions in the suspected area ( $p = 0.001$ ). Difficulty with insufflation and the  
167 presence of stenosis were also more frequently observed ( $p < 0.001$ ). In the non-GLP group,  
168 there was a higher proportion of patients with a single ulcer or ulcer-budding tumor ( $p <$   
169  $0.001$ ). On endoscopic ultrasound, there was more frequent thickening on at least one  
170 segment ( $p < 0.04$ ) or pangastric thickening in the GLP group ( $p < 0.001$ ). This one was more  
171 frequently circumferential with predominance over the third hyperechoic layer or fusion  
172 aspect of the layers ( $p < 0.001$ ).

### 173 **Imaging**

174 On contrast-enhanced computed tomography scan (13% with opacification with water or  
175 contrast medium), we observed a higher proportion of diffuse parietal involvement and  
176 circumferential thickening of the gastric wall.

### 177 **Biology**

178 Among all the biological parameters studied, only anemia was significantly more frequent in  
179 the non-GLP group. No significant differences were observed on the other characteristics of  
180 blood count and CRP, serum albumin and tumor marker elevation frequency (ACE and CA  
181 19-9) between both groups.

### 182 **Pathological findings**

183 The comparative analysis of the histological characteristics of the gastrectomy specimens is  
184 presented in Table 3. Again, we noted several statistically significant differences between  
185 the two groups. In the GLP group, the number of total gastrectomy was higher with more  
186 incomplete resection. The disease was more frequently pangastric with an increased  
187 number of T4 status, positive lymph nodes, distant metastases and poorly cohesive and/or  
188 SRC contingent. Among the patients with positive lymph nodes, we observed more  
189 frequently a N3 status in the GLP group than in the non-GLP group (45% vs 18%). Among the

190 patients with metastatic location, peritoneal carcinomatosis only was known preoperatively  
191 in 19 patients (14 in the GLP group and 5 in the non-GLP group) and found per-operatively in  
192 15 patients (10 in the GLP group and 5 in the non-GLP group). In 5 patients of the GLP group,  
193 the tumor was a mixed type (n = 4) or a majority mucinous type (n = 1), according to the  
194 WHO 2010 classification. Of note, HER2 status positivity was low and the proportion of  
195 patients with Helicobacter Pylori infection was similar in both groups.

#### 196 **Diagnostic score**

197 The diagnosis score for gastric LP is presented in Table 4. Regarding first results, six variables  
198 were selected to create the score. Three variables corresponding to uppergastrointestinal  
199 endoscopic characteristics, the presence of large folds and/or gastric thickening on at least  
200 one segment (1.5 points), pangastric infiltration (2 points) and presence of gastric stenosis (1  
201 point). Two variables corresponding to endoscopic ultrasound characteristics, a  
202 circumferential thickening on at least one segment (0.5 points) and predominance of the  
203 lesion on the third hyperechoic layer (1 point). And one variable on histological report on  
204 endoscopic biopsies, presence of poorly cohesive cells and/or signet ring cells (1.5 points).

205 The score performance was evaluated by ROC curve (Figure 2), with an AUC of 0.967 [0.948 -  
206 0.987], a sensitivity of 94% [89.9-97.3] and a specificity of 88.7% [81.7-95.8] for a threshold  
207 of 2.75 points (observed performances on one of the 20 imputed datasets).

208 After internal bootstrap validation (resampling), the corrected AUC was 0.959.

209 **DISCUSSION:**

210 **GLP: a clearly different entity**

211 Firstly, our results confirmed that GLP tumor have to be considered as a different entity  
212 from non-GLP tumors with different epidemiological, clinical, radiological and histological  
213 presentation. The importance of the differences observed at diagnosis between these two  
214 types of gastric tumors makes it necessary to use a reliable tool that clearly differentiates  
215 them.

216 **A new diagnostic score for GLP**

217 To our knowledge, we are reporting the first diagnostic score to discriminate GLP from other  
218 GA. This score has an excellent diagnostic performance to predict the existence of GLP with  
219 an AUC of 0.967, a sensitivity of 94% and a specificity of 88.7% for a threshold of 2.75 points.  
220 The resampling by bootstrap allowed us to obtain an internal validation of the score  
221 performances with a corrected AUC of 0.959 with reinforce its viability. The 2/1 ratio  
222 between the GLP and the non-GLP group and the absence of a priori selection of the control  
223 group allows a satisfactory validation sample to be obtained.

224 The six variables used to create the score include 3 endoscopic parameters: the presence of  
225 large folds and / or parietal thickening on at least one segment (1.5 points), pangastric  
226 infiltration (2 points) and the presence of gastric stenosis (1 point); 2 endoscopic ultrasound  
227 parameters: circumferential thickening on at least one segment (0.5 points) and thickening  
228 of the third hyperechoic layer (1 point) and a histological parameter: presence of poorly  
229 cohesive and/or SRC (1.5 points).

230 GLP group was identified using 3 strict criteria based on histological analysis of the  
231 gastrectomy specimen which is considered as the gold standard for the positive diagnosis of  
232 GLP. In addition, this diagnosis was validated by a centralized review of histological reports

233 by a pathologist from a center specializing in the management of oesogastric tumors using a  
234 keyword grid and in some cases a re-reading of the glass slides. As LP is a rare entity,  
235 obtaining a group of 71 patients who were included using only the current gold standard can  
236 be considered a large sample. Among the various parameters analyzed to create the score,  
237 many differed significantly between the two samples. The differences in clinical, endoscopic,  
238 scannographic and histological presentation observed in the GLP group have been previously  
239 reported in the literature underlining the quality of our sampling (8,9,16). The percentage of  
240 patients with SRC adenocarcinoma (22%) in the control group was also in agreement with  
241 the literature (17–19).

242 **GLP: a lack of a consensual definition to date**

243 Histological analysis of the surgical specimen is not a tool that can be easily used in clinical  
244 practice given the high frequency of GLP who will never be operated on, mainly because of  
245 the greater aggressiveness of this pathology. Therefore, the definitions currently proposed  
246 are mainly based on upper gastrointestinal endoscopy. Thus, Pedrazzani et al (20) defined  
247 GLP as a thickening and stiffening of the gastric wall which involve circumferentially at least  
248 one-third of the stomach, and Endo et al (21) more than two thirds of the stomach. More  
249 recently, Agnes et al (9) proposed the following definition: thickening of the gastric wall,  
250 with lack of distensibility, which involves more than one third of the gastric surface, both as  
251 a circumferential involvement of more than one area, or a semi-circular involvement of  
252 more than two areas. Finally Jung et al (16) proposed a decisional algorithm to diagnose GLP  
253 based on macroscopic and microscopic data of the initial upper gastrointestinal endoscopy.  
254 However, these definitions are not validated and the inter-observer reproducibility of the  
255 description of endoscopic lesions is not known.

256

257 **GLP: a new diagnostic score that uses routine exams**

258 Endoscopic ultrasound is usually recommended for the diagnosis of GLP but its diagnostic  
259 value in distinguishing it from classical GA has never been studied (22). Endoscopic  
260 ultrasound puncture seems a useful tool in difficult cases but remains poorly evaluated and  
261 most often useless (23). Although the presence of poorly cohesive cells and/or SRC is almost  
262 constant in GLP, they can frequently be found in diffuse gastric adenocarcinomas and  
263 therefore do not constitute a discriminant parameter. Our score allows the diagnosis of GLP  
264 to be carried out with high sensitivity and specificity using usual explorations for the  
265 diagnosis of GA. Even if the inter-observer reproducibility of the different examinations is  
266 poorly known, the description of the macroscopic aspect on the upper gastrointestinal  
267 endoscopy, the analysis of the different gastric wall layers in endoscopic ultrasound and the  
268 histological description of gastric tumors represent routine procedures applicable in current  
269 practice to establish a diagnostic score. Despite some differences, no discriminating clinical  
270 parameters were found in the GLP sample. This is in agreement with the literature which  
271 reports that gastric cancer symptoms are non-specific and that in the event of a positive  
272 diagnosis there is no clinical sign to distinguish a particular tumor subtype. The CT scan has  
273 been recently shown to be a useful tool for the diagnosis of GLP (24). This is confirmed by  
274 our data which show a significantly increased frequency of circumferential and/or pangastric  
275 parietal abnormalities. However, these two morphological parameters remain less  
276 discriminating than those observed on the upper gastrointestinal endoscopy and the  
277 endoscopic ultrasound.

278 **GLP diagnostic score: a new tool to standardize its management**

279 Despite the severity of this pathology, medico-surgical management of gastric LP remains  
280 poorly codified. The rarity of this gastric tumor, the absence of a consensual definition and



281 the confusion created by the term signet ring cell carcinoma contribute to the absence of  
282 therapeutic advances, although the GLP has different characteristics and a poorer prognosis.  
283 Other scores have already been validated in GA in patients treated, notably to establish  
284 survival predictive factors after gastrectomy (25–27) or in metastatic patients undergoing  
285 chemotherapy (28,29). The validation of a diagnostic score specific to GLP provides a new  
286 homogeneous pre-therapeutic definition that could standardize the management of this  
287 pathology, which is considered chemoresistant (30).

### 288 **Limitations**

289 Nevertheless, our study has some limitations. The data were collected retrospectively with a  
290 limited number of patients in the LP sample and no systematic centralized re-reading of all  
291 the glass slides. The retrospective design of the study led to some missing data. However, all  
292 the files including the pathology reports were centrally reviewed in order to reduce the  
293 number of missing data. Some inaccuracies in upper gastrointestinal endoscopy, endoscopic  
294 ultrasound and CT scan reports may also have led to misinterpretation of some data  
295 however this parameter has been taken into account in the creation of our score by  
296 performing multiple imputations using chain equations. Furthermore, our score was not  
297 externally validated in an independent cohort. Nevertheless, the rarity of this pathology and  
298 the difficulty of obtaining a homogeneous study group make it difficult to carry out such  
299 work.

300

### 301 **CONCLUSION:**

302 We have constructed and validated the first score to diagnose GLP with high sensitivity and  
303 specificity (Saint-Louis linitis score). This one is composed of six parameters easily applicable  
304 in clinical practice and allows to determine a homogeneous group of patients in a pathology

305 where there is no consensual definition. The use of this score may help to improve the  
306 therapeutic management of this subtype of GA, in particular the interest of preoperative  
307 chemotherapy and extend of gastric resection if planned. However an external validation is  
308 necessary in order to integrate this new score into clinical practice.

**TABLES:**

Variables	GLP N = 71		Non-GLP N = 149		P value
Gender, n (%)					
Female/Male	35/36	(49/51)	45/104	(30/70)	<b>0.007</b>
Age at diagnosis (years)					
Median (IQR)	57	(45.5-63)	64	(56-71.5)	<b>&lt;0.001</b>
Time to first symptoms - cancer diagnosis (days)					
Median (IQR)	103	(72-184)	67	(17-181)	<b>0.02</b>
Tumor stage at diagnosis, n (%)					
Localized tumor	57	(80)	142	(95)	
Metastatic tumor	14	(20)	7	(5)	
Pre-operative treatment					
Upfront surgery	24	(34)	69	(46)	
Systemic chemotherapy	47	(66)	80	(54)	
Systemic chemotherapy + PIPAC *, n (%)	2	(3)	0	(0)	
Clinical symptoms at diagnosis, n (%) **					
Poor general status	41	(58)	39	(26)	<b>&lt;0.001</b>
Undernutrition	32	(45)	40	(27)	<b>0.002</b>
Dysphagia	14	(20)	6	(4)	<b>&lt;0.001</b>
Epigastric pain	58	(82)	97	(65)	<b>0.01</b>
Vomiting	11	(15.5)	14	(9.5)	0,255
Digestive hemorrhage	4	(5.5)	25	(17)	<b>0.03</b>
Occlusive syndrome	7	(10)	7	(5)	0,151
Perforation	3	(4)	4	(3)	0,684
Histological diagnosis, n (%)					
Unique upper digestive endoscopy	49	(69)	140	(94)	<b>&lt;0.001</b>
Repeated upper digestive endoscopies	9	(12.5)	7	(5)	<b>&lt;0.001</b>
Upper endoscopic ultrasound	2	(3)	1	(0.5)	
Exploratory coelioscopy	7	(10)	0	(0)	
Inaugural surgery	4	(5.5)	1	(0.5)	

**Table 1:** General characteristics of the study population

\* Pressurized intraperitoneal aerosol chemotherapy

\*\* Several symptoms may be associated

Variables	GLP N = 71		Non-GLP N = 149		P value
Upper gastrointestinal endoscopy, n (%) *					
Single ulcer	27	(38)	79	(53)	<b>0.04</b>
Ulcerations or multiple erosions	16	(22.5)	10	(6.5)	<b>0.001</b>
Ulcer-budding tumor	4	(5.5)	53	(35.5)	<b>&lt;0.001</b>
Large gastric folds or thickening on one segment	40	(56)	9	(6)	<b>&lt;0.001</b>
Large gastric folds or diffuse thickening	15	(21)	0	(0)	<b>&lt;0.001</b>
Difficulty of insufflation	13	(18)	0	(0)	<b>&lt;0.001</b>
Stenosis	21	(29.5)	18	(12)	<b>0.001</b>
Pangastric tumor infiltration	17	(24)	0	(0)	<b>&lt;0.001</b>
Tumor infiltration extending to the duodenal bulb	8	(11)	1	(1)	<b>&lt;0.001</b>
Tumor diagnosis not mentioned on the macroscopic aspect	16	(22.5)	4	(3)	<b>&lt;0.001</b>
Upper endoscopic ultrasound, n (%) *					
Circumferential thickening	28	(39.5)	8	(5.5)	<b>&lt;0.001</b>
Pan gastric thickening	13	(18)	0	(0)	<b>&lt;0.001</b>
Thickening of an entire segment or a limited part	33	(46.5)	77	(52)	<b>0.004</b>
Wall thickening predominant on the 3rd hyperechoic layer	15	(21)	0	(0)	<b>&lt;0.001</b>
Layer fusion	14	(20)	11	(7.5)	<b>0.008</b>
Suspicious peri-gastric adenopathy	26	(36)	44	(29.5)	0,585
Scanner, n (%) **					
Localized parietal abnormality	43	(60.5)	95	(64)	0,63
Diffuse parietal abnormality	19	(27)	4	(3)	<b>&lt;0.001</b>
Circumferential parietal abnormality	33	(46.5)	17	(11.5)	<b>&lt;0.001</b>
Suspicious peri-gastric adenopathy	21	(29.5)	66	(44)	0,128

**Table 2:** Characteristics of endoscopic findings and imaging in the study population

\* Several possible lesions in the same patient

\*\* Parietal abnormalities = thickening +/- parietal enhancement or endoluminal bud

Variables	GLP N = 71		Non-GLP N = 149		P value
Type of gastrectomy, n (%)					
Total	61	(86)	86	(58)	<0.001
Partial	10	(14)	63	(42)	<0.001
Resection, n (%)					
R0	46	(65)	141	(94)	<0.001
R1	25	(35)	7	(5)	
R2	0	(0)	1	(1)	
Tumour site, n (%)					
Pangastric	30	(42)	0	(0)	<0.001
Fundus	12	(17)	28	(19)	
Antrum/pylorus	24	(34)	93	(62)	
Antro-fundic junction or body	5	(7)	28	(19)	
AJCC TNM stage, n (%) *					
pT1-T2	2	(3)	64	(43)	
pT3-T4	69	(97)	85	(57)	
Positive lymph nodes (any N)	55	(75.5)	85	(57)	<0.001
M1 (metastatic location)	24	(34)	12	(8)	<0.001
WHO classification, n (%)**					
Poorly cohesive (including signet ring cells)	66	(93)	33	(22)	
Tubular	0	(0)	60	(40.5)	
Papillary	0	(0)	6	(4)	
Mucinous	1	(1.5)	5	(3.5)	
Mixed	4	(5.5)	21	(14)	
Unknown	0	(0)	24	(16)	
Lymph node(s)					
Number of lymph nodes analyzed, median (IQR)	26	(18-34)	22	(16-31)	0,054
Number of invaded lymph nodes, median (IQR)	8	(3-13)	4	(3-9)	<0.001
HER2, n (%)***					
Positive	1	(1.5)	12	(8)	0,112
Not determined	16	(22.5)	19	(13)	

**Table 3:** histological characteristics of the gastrectomy specimens

\* UICC/AJCC 2016

\*\* WHO classification 2010

\*\*\* HER2 status has sometimes been determined on endoscopic biopsies

Items	$\beta^*$	Point
Upper gastrointestinal endoscopy		
Large folds and / or gastric thickening on at least one segment	3.18	1.5
Pangastric infiltration	4.33	2
Stenosis	1.63	1
Upper endoscopic ultrasound		
Circumferential thickening	0.18	0.5
Thickening of the gastric wall predominant on the third hyperechoic layer	2.49	1
Histology of gastric biopsies		
Poorly cohesive and/or signet ring cells	3.14	1.5

**Table 4:** Diagnostic score of gastric linitis plastica

Each item scores 0 if absent or the tabulated value if present. The diagnostic score is the sum of each items and ranges from 0 to 7.5; a higher score indicates a higher probability of linitis plastica. The chosen threshold is 3: patients with a score <3 are considered not having a gastric linitis plastica and patients with a score  $\geq 3$  are considered having a gastric linitis plastica

\*  $\beta$  coefficient are obtained with Firth penalized logistic regression model

**Figure 1:** Flow chart of the whole population

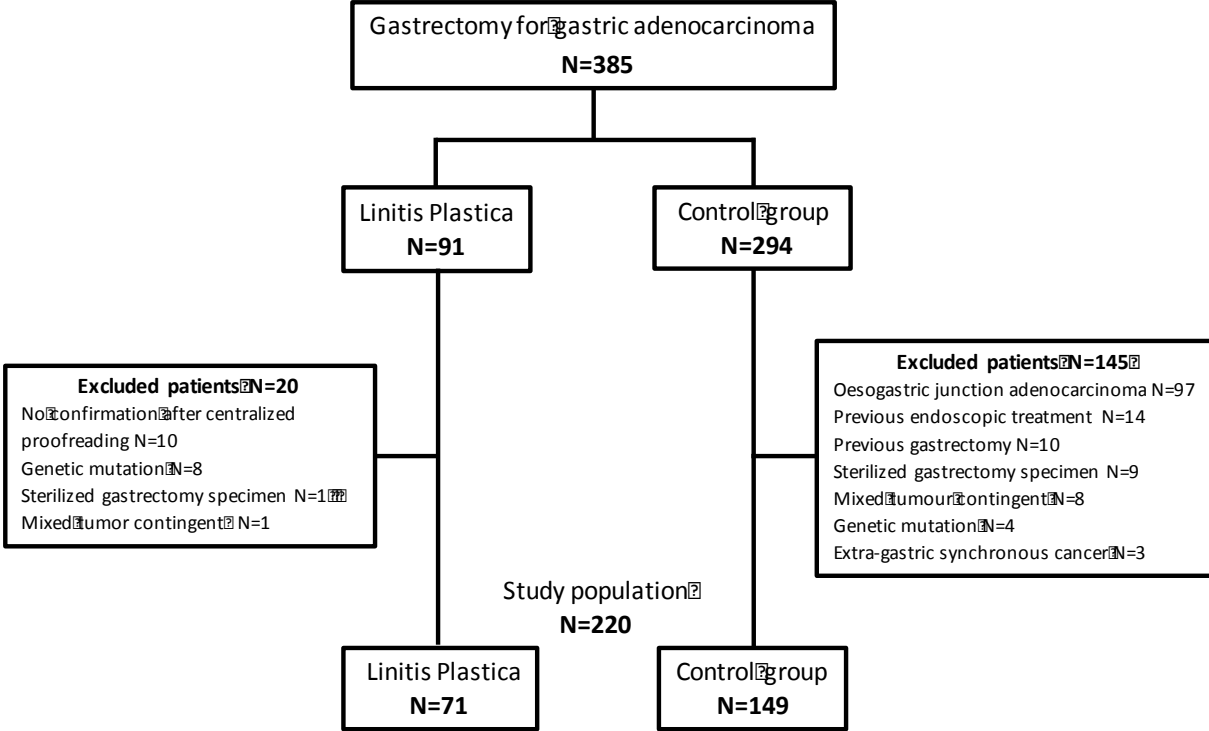
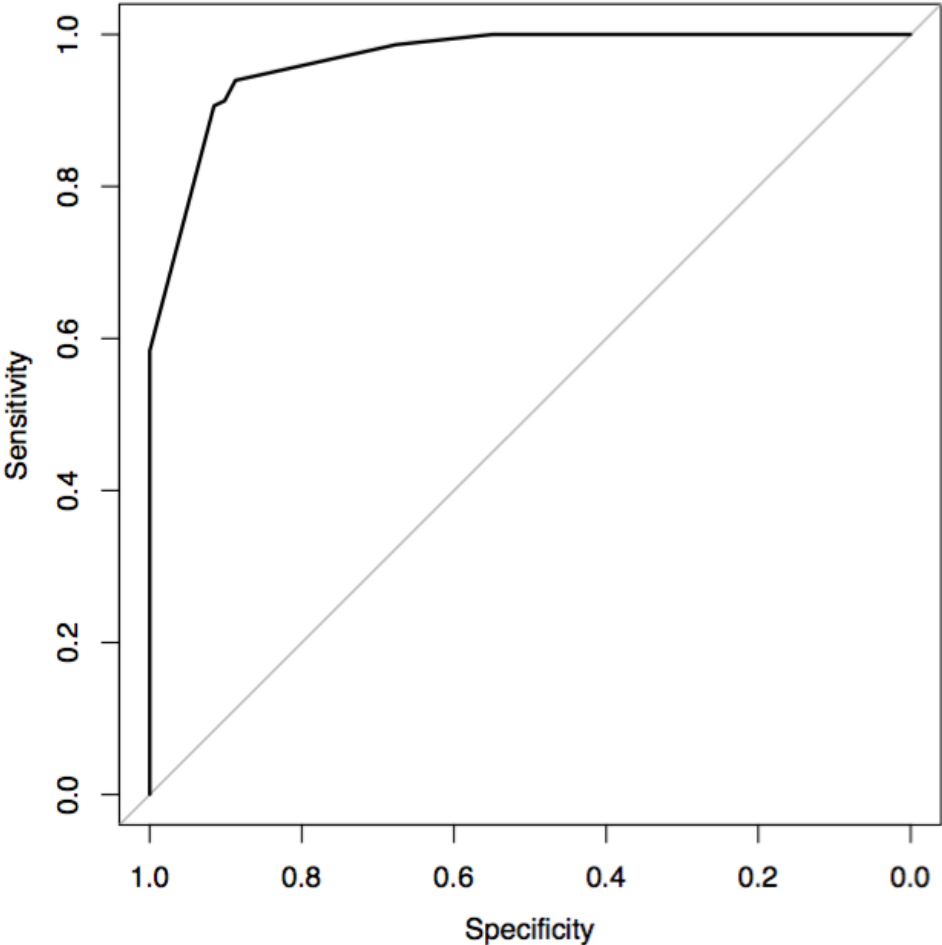


Figure 2 : ROC curve





## FIGURES LEGENDS

Figure 1: Flow chart

Figure 2: ROC curve. The AUC is 0,967 [0.948 - 0.987]; using a threshold of 2.75, the sensitivity is 94% [89,9-97,3] and the specificity is 88,7% [81,7-95,8].

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions.

All the authors declare no conflict of interest for this article (ICMJE Form for Disclosure of Potential Conflicts of Interest).

All data were anonymously collected and, according to the Loi Jardé, no patient consent was needed, as the treatment implemented in this study was the standard recommended therapy.

**SUPPLEMENTARY TABLES S1 to S6:** unadjusted association between each candidate predictor and outcome. using Firth's bias-Reduced penalized-likelihood logistic regression.

**Table S1 : Clinical Variables**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Age	0.94	[0.92 - 0.97]	<b>&lt;0.001</b>	1
Gender	0.45	[0.25 - 0.8]	<b>0.0064</b>	0
Time to first symptoms-cancer diagnosis	1	[1 - 1.01]	0.14	70
Epigastric pain	2.33	[1.21 - 4.75]	<b>0.011</b>	0
Dysphagia	5.57	[2.18 - 15.76]	<b>&lt;0.001</b>	0
Vomiting	1.78	[0.76 - 4.07]	0.18	0
Poor general status	3.9	[2.16 - 7.14]	<b>&lt;0.001</b>	2
Upper digestive hemorrhage	0.33	[0.1 - 0.85]	<b>0.02</b>	0
Iron deficiency anemia	0.18	[0.05 - 0.51]	<b>&lt;0.001</b>	0
Stenosing gastric tumor	2.21	[0.76 - 6.47]	0.14	0
Perforation	1.65	[0.36 - 6.97]	0.5	0
Undernutrition	2.64	[1.44 - 4.88]	<b>0.0018</b>	14

**Table S2 Biological Variables**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Anemia	0.45	[0.24 - 0.81]	<b>0.0084</b>	15
Elevated C-reactive protein	1.33	[0.58 - 3.1]	0.5	99
Increased neutrophils count	0.7	[0.27 - 1.64]	0.42	37
Lymphopenia	0.52	[0.18 - 1.33]	0.18	54
Neutrophil-to-lymphocytes ratio	1	[0.91 - 1.07]	0.92	54
Thrombocytosis	0.23	[0.04 - 0.73]	0.011	35
Hypoalbuminemia	1.64	[0.82 - 3.27]	0.16	56
Increased CEA	0.36	[0.09 - 1.06]	0.064	38
Increased CA 19-9	0.76	[0.31 - 1.76]	0.53	47

**Table S3 Upper Gastrointestinal Endoscopy Variables**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Single ulcer	0.54	[0.3 - 0.95]	<b>0.033</b>	4
Ulcerations or multiples erosions	3.94	[1.73 - 9.33]	<b>0.0011</b>	4
Ulcer-budding tumor	0.12	[0.04 - 0.3]	<b>&lt;0.001</b>	4
Large gastric folds or thickening on one segment	19.36	[8.96 - 45.67]	<b>&lt;0.001</b>	3
Large gastric folds or diffuse thickening	82.95	[10.85 - 10653.78]	<b>&lt;0.001</b>	2
Difficulty of insufflation	73.57	[9.49 - 9472.06]	<b>&lt;0.001</b>	5
Stenosis	3.19	[1.58 - 6.52]	0.0013	4
Pangastric tumor infiltration	97.15	[12.83 - 12457.88]	<b>&lt;0.001</b>	2
Fundic tumor site	1.79	[0.94 - 3.38]	0.077	3
Antral tumor site	0.43	[0.23 - 0.78]	<b>0.0049</b>	2
Antro-fundic junction or body tumor site	0.56	[0.28 - 1.07]	0.082	3
Tumor infiltration extending to the duodenal bulb	13.59	[2.97 - 129.6]	<b>&lt;0.001</b>	3
Tumor diagnosis not mentioned on the macroscopic aspect	5	[2.11 - 12.66]	<b>&lt;0.001</b>	2
Repeated diagnosis upper endoscopy	0.22	[0.1 - 0.45]	<b>&lt;0.001</b>	0

**Table S4 Upper Endoscopic Ultrasound Variables**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Circumferential thickening	13.33	[5.56 - 34.98]	<b>&lt;0.001</b>	88
Pangastric thickening	68.91	[8.71 - 8908.76]	<b>&lt;0.001</b>	89
Thickening of an entire segment or a limited part	0.24	[0.09 - 0.63]	<b>0.0034</b>	90
Wall thickening predominant on the 3 rd hyperechoic layer	96.51	[12.24 - 12473.83]	<b>&lt;0.001</b>	97
Layer fusion	3.35	[1.38 - 8.36]	0.0076	99
Suspicious perigastric adenopathy	1.26	[0.62 - 2.59]	0.52	87

**Table S5 CT Scan variables**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Localized parietal abnormality	0.82	[0.45 - 1.54]	0.54	17
Diffuse parietal abnormality	12.02	[4.43 - 40.03]	<b>&lt;0.001</b>	15
Suspicious perigastric adenopathy	0.61	[0.33 - 1.11]	0.1	9

**Table S6 histological variables (endoscopic biopsies)**

Variables	Odds Ratio (OR)	95% CI	P value OR	Missing data (N)
Diffuse fibrous stromal reaction	7.49	[3.12 - 20.51]	<b>&lt;0.001</b>	62
Mixed gastric tumor	0.62	[0.23 - 1.5]	0.3	6
Signet ring cells	29.53	[11.81 - 94.1]	0	4
Positive HER 2 status	0.26	[0.03 - 1.12]	0.075	35
Positive Helicobacter Pylori status	0.81	[0.39 - 1.66]	0.57	72
Low-tumor burden	2.23	[1.11 - 4.46]	<b>0.025</b>	29

**Supplementary Table S7 (Tripod checklist)**

Section/Topic		Checklist Item	Page
<b>Title and abstract</b>			
Title	1	Identify the study as developing and/or validating a multivariable prediction model, the target population, and the outcome to be predicted.	1
Abstract	2	Provide a summary of objectives, study design, setting, participants, sample size, predictors, outcome, statistical analysis, results, and conclusions.	2 and 3
<b>Introduction</b>			
Background and objectives	3a	Explain the medical context (including whether diagnostic or prognostic) and rationale for developing or validating the multivariable prediction model, including references to existing models.	4 and 5
	3b	Specify the objectives, including whether the study describes the development or validation of the model or both.	5
<b>Methods</b>			
Source of data	4a	Describe the study design or source of data (e.g., randomized trial, cohort, or registry data), separately for the development and validation data sets, if applicable.	6
	4b	Specify the key study dates, including start of accrual; end of accrual; and, if applicable, end of follow-up.	6
Participants	5a	Specify key elements of the study setting (e.g., primary care, secondary care, general population) including number and location of centres.	6
	5b	Describe eligibility criteria for participants.	6
	5c	Give details of treatments received, if relevant.	Not relevant
Outcome	6a	Clearly define the outcome that is predicted by the prediction model, including how and when assessed.	6 and 7
	6b	Report any actions to blind assessment of the outcome to be predicted.	Not relevant
Predictors	7a	Clearly define all predictors used in developing or validating the multivariable prediction model, including how and when they were measured.	Table 1 and 2
	7b	Report any actions to blind assessment of predictors for the outcome and other predictors.	7
Sample size	8	Explain how the study size was arrived at.	6
Missing data	9	Describe how missing data were handled (e.g., complete-case analysis, single imputation, multiple imputation) with details of any imputation method.	8
Statistical analysis methods	10a	Describe how predictors were handled in the analyses.	8
	10b	Specify type of model, all model-building procedures (including any predictor selection), and method for internal validation.	7 and 8
	10d	Specify all measures used to assess model performance and, if relevant, to compare multiple models.	7 and 8
Risk groups	11	Provide details on how risk groups were created, if done.	Not

			relevant
<b>Results</b>			
Participants	13a	Describe the flow of participants through the study, including the number of participants with and without the outcome and, if applicable, a summary of the follow-up time. A diagram may be helpful.	10, figure 1
	13b	Describe the characteristics of the participants (basic demographics, clinical features, available predictors), including the number of participants with missing data for predictors and outcome.	Table 1-3
Model development	14a	Specify the number of participants and outcome events in each analysis.	10-12
	14b	If done, report the unadjusted association between each candidate predictor and outcome.	Table 1 and Sup S1-S5
Model specification	15a	Present the full prediction model to allow predictions for individuals (i.e., all regression coefficients, and model intercept or baseline survival at a given time point).	Table 4
	15b	Explain how to use the prediction model.	Table 4
Model performance	16	Report performance measures (with CIs) for the prediction model.	12, Figure 2
<b>Discussion</b>			
Limitations	18	Discuss any limitations of the study (such as nonrepresentative sample, few events per predictor, missing data).	16
Interpretation	19b	Give an overall interpretation of the results, considering objectives, limitations, and results from similar studies, and other relevant evidence.	13-16
Implications	20	Discuss the potential clinical use of the model and implications for future research.	15-17
<b>Other information</b>			
Supplementary information	21	Provide information about the availability of supplementary resources, such as study protocol, Web calculator, and data sets.	Not done
Funding	22	Give the source of funding and the role of the funders for the present study.	Not relevant

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