

**The psoas muscle transversal diameter predicts mortality in patients with cirrhosis on a waiting list for liver transplantation A retrospective cohort study**

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1 **The psoas muscle transversal diameter predicts mortality in patients with cirrhosis on**  
2 **waiting-list for liver transplantation: a retrospective cohort study**

3  
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27

28 Running title: psoas and liver transplantation

29 **Highlights**

- 30 • Transversal psoas thickness index (TPTI) is measured on an umbilicus-targeted CT.
- 31 • TPTI was independently associated with mortality.
- 32 • TPTI is easy, quick, cheap, and highly reproducible, reliable by a non-expert operator.
- 33 • TPTI could be a marker of muscle mass and function.

34

35 Abbreviations list:

36 ADPM, axial diameter of psoas muscle

37 APTI, axial psoas thickness index

38 AUC, area under the curve

39 BMI, Body mass index

40 BIA, bioimpedance analysis

41 CI, confidence interval

42 CT, computed tomography

43 DEXA, dual-energy X-ray absorptiometry

44 INR, International Normalized Ratio

45 MAMC, midarm muscle circumference

46 MELD, Model For End-Stage Liver Disease

47 MRI, magnetic resonance imaging

48 ROC, receiving operating characteristic

49 SD, standard deviation

50 TDPM, transversal diameter of psoas muscle

51 TPTI, transversal psoas thickness index

52

53 Conflict of interest statement: none. The authors have no conflict of interest to declare.

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55 **ABSTRACT**

56 **Objective:** Malnutrition impairs prognosis in liver cirrhosis. Aims: to determine: if transversal  
57 (TPTI) and axial (APTI) psoas thickness indices predict mortality in cirrhotic patients; feasibility  
58 and reproducibility of psoas muscle transversal (TDPM) and axial (ADPM) diameters  
59 measurements. **Research Methods & Procedures:** Retrospective study. Inclusion criteria:  
60 cirrhosis on liver transplantation waiting list, abdominal CT scan within the three months  
61 preceding list inscription. TDPM and ADPM were measured on a single umbilicus-targeted CT  
62 image by non-expert and expert operators. TPTI or APTI (mm/m) were calculated as: TDPM or  
63 ADPM/height (m). Statistics: mortality prediction and associated variables: area under the  
64 receiver operating characteristic curve (AUC) and Cox proportional hazard models assessed.  
65 TPTI and APTI interobserver agreement: kappa (k) correlation test. **Results:** 173 patients were  
66 included. Low TPTI was associated with increased mortality: AUC=0.66 [95% confidence  
67 interval, 0.51–0.80]. TPTI was the only factor associated with mortality (hazard ratio=0.87, 95%  
68 confidence interval 0.76–0.99, P=0.034). There was an almost perfect interobserver agreement  
69 between the two operators: TDPM, k=0.97; ADPM, k=0.94; P<0.0001. **Conclusion(s):** TPTI  
70 measured on umbilicus-targeted CT scan before inscription on waiting-list for liver  
71 transplantation predicts mortality of cirrhotic patients. TPTI measurement is easy and reliable,  
72 even by a non-trained operator, then highly feasible in the daily clinical practice.

73

74 Keywords: muscle mass; malnutrition; computed tomography scan; liver failure

## 75 INTRODUCTION

76 Chronic liver diseases are often complicated with malnutrition [1], that impairs the prognosis  
77 [2,3]. Nevertheless, because of rapid fluid shifts and altered water compartmentalization due to  
78 ascites and oedema, standard methods of nutritional assessment (weight loss, body mass index,  
79 biological markers, i.e. albumin, transthyretin, or multicomposite scores) are not usable. Also,  
80 body composition assessment methods, such as bioimpedance analysis (BIA) or dual-energy X-  
81 ray absorptiometry (DEXA) [4,5] are not applicable to patients with liver cirrhosis (BIA) [6], or  
82 not routinely applicable in the daily clinical practice (DEXA) [7]. Liver cirrhosis is associated  
83 with significant changes in body composition: the prevalence of muscle mass loss is estimated to  
84 be 20-60% [8,9]; muscle mass loss is an independent prognostic factor in cirrhosis [10]. Mid-arm  
85 muscle circumference is an independent predictor of survival in patients with liver cirrhosis [11],  
86 but its interobserver variability limits its use in the daily practice. In the last decade, the  
87 development of cross sectional imaging techniques, such as computed tomography (CT) or  
88 magnetic resonance imaging (MRI) [12], is very promising to assess muscle mass. Developed  
89 from studies conducted in oncology [13], disease prognosis could be assessed by the whole  
90 muscle cross sectional area measured on a third lumbar vertebra (L3)-targeted CT normalized by  
91 height. This L3 skeletal muscle index predicted mortality after liver transplantation [14-16], and  
92 recently in cirrhotic patients on waiting-list for liver transplantation [17,18]. However this  
93 technique could be time-consuming. Therefore there is a need to develop simpler and easier  
94 methods to assess muscle mass, doable for all in the daily clinical practice. Psoas muscle  
95 measurement could appear as a reliable marker to assess cirrhosis prognosis. Recently, Golse et  
96 al suggested that psoas muscle area better predicts post-liver transplantation 1-year survival than  
97 L3 skeletal muscle index, but they did not assess the predictive role of transversal psoas muscle  
98 thickness [19]. Durand et al showed that the measurement of the transversal psoas muscle  
99 thickness by CT images targeted on the umbilicus, standardized to height, was an independent

100 predictive factor for mortality in cirrhotic patients with refractory ascites on waiting-list for liver  
101 transplantation [20]. However these results were never confirmed by an independent study, nor  
102 in a whole population of cirrhotic patients on waiting-list for liver transplantation. Therefore, the  
103 main aim of this retrospective study was to determine whether the measurement of the  
104 transversal or axial diameter of the psoas muscle on an abdominal CT predicted mortality in  
105 patients with cirrhosis on waiting-list for liver transplantation. The secondary aims were to  
106 determine the feasibility and reliability of the measurements of transversal or axial psoas muscle  
107 diameters by a non-trained operator.  
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## 109 **METHODS**

### 110 **Study design**

111 A monocentric observational retrospective study was conducted in the Department of Liver  
112 Transplantation and the Hepatic diseases Unit of the Rennes University Hospital (CHU Rennes),  
113 Rennes, France. Our unit is a tertiary referral centre for liver transplantation in France.

114

### 115 **Patients' recruitment**

116 All patients with liver cirrhosis registered on the waiting-list for liver transplantation for isolated  
117 cirrhosis from 01/01/2011 to 31/12/2014 were eligible. The date of 01/04/2011 was chosen  
118 because CT-scan images are included in the CHU Rennes computerized medical records only  
119 since this date. To be included, patients must have undergone an abdominal CT scan within the 3  
120 months before registering on the waiting-list for liver transplantation. Exclusion criteria were  
121 hepatocellular carcinoma as the indication for liver transplantation, multi-organ transplant, and  
122 temporary contraindication to transplantation during the follow-up. The study protocol  
123 conformed to the ethical guidelines and the 1975 Declaration of Helsinki as reflected in a priori  
124 exemption by the appropriate institutional review committee.

125

### 126 **Study endpoints**

127 The primary endpoint was the occurrence of death on waiting-list for liver transplantation. As  
128 previously published [14], patients removed from the transplantation waiting list because of the  
129 worsening of their liver cirrhosis were considered as deaths. The secondary endpoint was the  
130 reliability of the measurements of transversal (TDPM) and axial (ADPM) diameters of the psoas  
131 muscle by a non-trained operator.

132

### 133 **Measurement of psoas muscle diameters**



134 The measurements of the axial and transverse diameters of the right psoas were performed on  
135 one single CT scan image targeted on the umbilicus. We chose to assess psoas muscle diameters  
136 on umbilicus-targeted scan, because the study by Taguchi et al [21] indicated that axial and/or  
137 transversal psoas thickness at the umbilicus level was more associated with mortality than at the  
138 L3 level, in patients with metastatic urothelial carcinoma; Durand et al used this method in  
139 cirrhotic patients; the recent study by Golse et al [19] compared L3-targeted psoas muscle area to  
140 SMI, but they did not assess the predictive role of the axial or transversal diameters of the psoas  
141 muscle. The assessment was performed by one single non expert-operator (AH), a  
142 gastroenterologist fellow without any specific skill in radiology. For the first 50 patients, the  
143 measurements were checked by a radiologist specialized in Gastrointestinal Imaging, blinded of  
144 the first operator's measurement. The operators were blinded from the demographics and clinical  
145 data including mortality on liver transplantation list. The axial diameter of psoas muscle  
146 (ADPM) was determined as the longest antero-posterior diameter and expressed in millimetre  
147 (mm) (**Figure 1**). The transversal diameter of the psoas muscle (TDPM) was defined as the  
148 diameter perpendicular to the axial diameter (**Figure 1**). Axial psoas thickness index (APTI),  
149 was expressed as mm/m, and calculated as: ADPM (mm)/height (m). Transversal psoas  
150 thickness index (TPTI) was expressed as mm/m, and calculated as: TDPM (mm)/height (m).

151

## 152 **Data collection**

153 The list of patients fulfilling the eligibility criteria was obtained by extraction from the Cristal®  
154 software, the computerized biomedicine agency database. The data were then collected by  
155 consultation of computerized files and included age, gender, body weight, height, aetiology of  
156 cirrhosis, year of cirrhosis diagnosis, presence of ascites (none, refractory), presence of hepatic  
157 encephalopathy, serum albumin, serum bilirubin, prothrombin time, serum sodium level, and  
158 serum creatinine. Clinical and laboratory data were obtained at the registration on liver

159 transplantation list. Child Pugh and Model for End-Stage Liver Disease (MELD) scores were  
160 calculated.

161

### 162 **Statistical analysis**

163 Variables are expressed as mean  $\pm$  standard deviation (SD) or percentage. Means were compared  
164 with Student t or Wilcoxon test as appropriate. Univariate analysis was performed by Cox  
165 proportional hazards model with a significance level of  $P < 0.05$ . Variables significant ( $P < 0.2$ ) in  
166 univariate analysis were included in the multivariate analysis. To select the optimal cut-off of  
167 psoas muscle index associated with the primary endpoint, receiver operating characteristic  
168 (ROC) curve and the Youden method were used. Survival rates of subgroups of patients were  
169 calculated with Kaplan Meier method, and compared by the log-rank test. Patients transplanted  
170 and removed of transplantation list because they had an improvement of the liver disease or for  
171 personal decision were censored. Interobserver agreement of the measurements of axial (ADPM)  
172 and transversal (TDPM) diameters of the psoas muscle were analysed by kappa correlation test.  
173 Data were analysed using SPSS version 22 (SPSS Inc., Chicago, IL, USA). P value less than  
174 0.05 was considered significant with a two-tailed test.

175

## 176 RESULTS

### 177 Patients' selection

178 The study flow chart is shown in **Figure 2**. Among the 175 eligible patients, 173 were enrolled  
179 into the study and included in the final analysis.

180

### 181 Patients' characteristics and outcomes

182 The characteristics of the 173 included patients at the time of their registration on liver  
183 transplantation list are detailed in **Table 1**. The most frequent aetiology of liver cirrhosis was  
184 alcoholic (71%). Most of cirrhotics were CHILD C (66%). The mean MELD score at registration  
185 was  $21.2 \pm 8.1$ . Forty-seven percent of cirrhotics were complicated with refractory ascites. During  
186 the mean follow-up of  $5.6 \pm 6.2$  month, 143 patients were transplanted (82.7%) and 13 died  
187 (7.5%). The remaining 17 patients (9.8%) were removed from the waiting-list because of disease  
188 improvement or personal decision. The mean time length on waiting-list before accessing to liver  
189 transplantation was  $5.3 \pm 6.4$  month. The mean time length on waiting-list before death was  
190  $7.3 \pm 6.8$  month.

191

### 192 Relation between psoas muscle thickness and mortality

193 The univariate analysis including the patients' characteristics at registration (gender, age, body  
194 mass index), disease variables (aetiology of cirrhosis, CHILD and MELD scores, ascites, hepatic  
195 encephalopathy, plasma bilirubin, albumin, prothrombin time, creatinine, and sodium), APTI and  
196 TPTI, is shown in **Table 2**. The CHILD score, the MELD score, refractory ascites, plasma  
197 creatinine and sodium, and TPTI, were significantly associated with death or exclusion of  
198 transplant list for worsening of the liver cirrhosis (**Table 2**). In the Cox multivariate analysis,  
199 only TPTI was independently and significantly ( $P < 0.05$ ) associated with mortality (**Table 3**).  
200 TPTI was associated with mortality: AUC=0.66 [95% confidence interval, 0.51–0.80] (**Figure**

201 **3A**). According to the optimal cut-off for predicting the occurrence of death with the ROC curve,  
202 muscle mass loss was defined as  $TPTI < 15.2$  mm/m and normal muscle mass as  $TPTI \geq 15.2$   
203 mm/m; then a low muscle mass was associated with higher mortality (log rank test:  $p < 0.01$ )  
204 (**Figure 3B**). Thirty-three percent of cirrhotic patients had low muscle mass at registration on  
205 waiting-list for liver transplantation, and had an overall mortality of 14% (vs. 4% in the normal  
206 muscle mass group).

207

208 **Feasibility and interobserver agreement of the measurements of transversal (TDPM) and**  
209 **axial (ADPM) diameters of the psoas muscle**

210 TDPM and ADPM measurements were easily performed in 100% of patients by the non-trained  
211 operator (AH). There was an almost perfect interobserver agreement: kappa coefficient  
212 correlations between the two operators-blinded TDPM and ADPM measurements (n=50) were  
213 respectively:  $k=0.97$ ,  $p < 0.0001$ ;  $k=0.94$ ,  $p < 0.0001$ . This very good agreement between two  
214 operators of opposite levels of radiologic expertise suggests the reliability of the measurements  
215 by a non-trained operator.

216

217 **DISCUSSION**

218 In this cohort of 173 patients with liver cirrhosis on waiting-list for liver transplantation, a low  
219 TDPM measured on an umbilicus-targeted CT scan image and normalized by height (i.e. TPTI)  
220 was independently associated with mortality. The increase of 1 mm/m of the TPTI was  
221 associated with a 13% decrease in death risk. This study confirms that the assessment of muscle  
222 mass from an abdominal CT scan is an accurate method to assess mortality in liver cirrhosis  
223 patients on waiting-list for liver transplantation. Our study clearly showed that the measurement  
224 of the transversal diameter of the right psoas muscle is an easy (i.e. no need for dedicated  
225 software such as for the measurement of L3 skeletal muscle index), quick, cheap (i.e. no  
226 additional costs as abdominal CT are routinely performed before registration on liver  
227 transplantation list), and highly reproducible method, and most of all, reliable by a non-expert  
228 operator, i.e. without any specific radiological competence. These make the TDPM the elective  
229 tool, accessible for all, to assess the liver cirrhosis prognosis for the daily clinical practice of  
230 Liver Disease, Radiology, and Liver Transplantation Departments.

231 Our study confirms the findings by Durand et al [20], but in a whole population of cirrhotic  
232 patients waiting for liver transplantation. Indeed, Durand et al only studied TPTI impact on  
233 mortality on liver transplantation waiting list in a subgroup of liver cirrhosis patients with  
234 refractory ascites and MELD<25 [19]. We found that the optimal TPTI cut-off to predict  
235 mortality was 15.22 mm/m with an AUC of 0.66. Comparable thresholds have been reported in  
236 the literature [16,20]. The recent study by Golse al [19] compared predictability for 1-year liver  
237 transplantation survival with different muscle indexes measured on a CT-scan cross section  
238 between L3 and the fourth lumbar vertebra: AUC values of right and left psoas muscle area,  
239 psoas muscles area normalized by height or body surface area, and the L3 skeletal muscle index,  
240 varied between 0.72 and 0.75. Psoas muscles area alone (below 1561 mm<sup>2</sup> in men, or below  
241 1464 mm<sup>2</sup> in women) best predicted survival [19]. This method looks like as less easy and more

242 time-consuming that the measurement of TPTI based on the right psoas only. The predictive role  
243 of the transversal diameters of the psoas muscles was not assessed by Golse et al [19]. More  
244 studies are needed in larger populations of cirrhotic patients to validate the optimal cut-off of  
245 TPTI or other muscle mass indexes, and most importantly the best indicator of muscle mass  
246 associated with long term prognosis. In all published studies, including the one presented here,  
247 the AUC values below 0.80 of the different muscle indexes suggested that the mortality  
248 prediction could be improved by associating muscle indexes prognostic with other variables  
249 associated with mortality such as refractory ascites or MELD, as previously suggested [8,20].  
250 Indeed a MELD-psoas score outperformed MELD score alone to predict mortality on liver  
251 transplant list in subgroups restricted to patients with refractory ascites [19], and previous history  
252 of variceal haemorrhage [8]. Future studies should focus on determining whether the  
253 combination of several predictive factors, e.g. TPTI and MELD score, could improve the  
254 mortality prediction after liver transplantation.

255 In our study, contrary to TPTI, MELD score alone was not associated ( $P < 0.08$ ) with mortality in  
256 the multivariable analysis. This was expected, because, since the MELD score is used to  
257 determine patients' priority to liver transplantation, the time to access to transplantation and the  
258 mortality on the waiting-list have been reduced. Therefore patients with higher MELD scores  
259 have a much shorter waiting time on transplantation list, thus better survival, than patients with  
260 lower MELD scores. However, the MELD score fails to identify patients with malnutrition or  
261 muscle mass loss, who, despite their poor prognosis related to malnutrition, are attributed a low  
262 MELD score, and therefore are not eligible for priority liver transplantation. In 2012, the French  
263 'Agence de Biomédecine' (Bio-Medicine Agency) reported that 20% of liver cirrhosis with a  
264 low MELD score were registered on waiting-list for liver transplantation. These included  
265 patients with cirrhosis complications, such as refractory ascites, encephalopathy, hepatorenal  
266 syndrome, hepatopulmonary syndrome, or malnutrition. In these cases, except for malnutrition,

267 the appeal to expert component allows deciding priority liver transplantation according to  
268 disease severity. Despite presumed muscle mass loss-related poor prognosis, malnutrition is not  
269 considered as a liver transplantation priority indication. Thanks to TPTI measurement, early  
270 identification of cirrhosis complicated with malnutrition, i.e. muscle mass loss, should allow  
271 triggering an early nutritional intervention with the aim to improve patients' outcome on waiting  
272 list for liver transplantation.

273 Anthropometric methods such as mid-arm muscle circumference should be abandoned because  
274 of their interobserver variability to assess muscle mass. Also in cirrhotic patients with ascites,  
275 bioimpedance analysis lacks of reliability [4-7]. However BIA-derived phase angle could be  
276 useful to assess cirrhotic patients' prognosis [21-23]. Beside radiologic assessment of muscle  
277 mass, the clinical assessment of muscle function, e.g. by handgrip strength measurement, could  
278 be of interest because of its prognostic value [24]. This remains to be demonstrated in liver  
279 cirrhosis patients on waiting-list for liver transplantation.

280 In our study, contrary to TPTI, APTI was not predictive of mortality. We have no clear  
281 explanation for this observation. This may be because the TDPM is more sensitive in case of  
282 catabolic situations associated to decreased protein synthesis such as malnutrition or reduced  
283 physical activity. The psoas muscle is involved in the ability of standing up, staying in the  
284 upright position, and walking. Therefore, we believe that TPTI could be a marker of muscle  
285 mass, as well as muscle function, both being related to prognosis [13-20;24-25]. This remains to  
286 be demonstrated in further studies.

287 In this retrospective study, the mechanisms underlying the relation between low psoas muscle  
288 transversal diameter and mortality were not explored. However we could hypothesize that  
289 increased mortality is due to a defect of immune response in relation with the decrease in protein  
290 reserves. This assumption is supported by our finding (data not shown) that infectious  
291 complications are the first cause of mortality (30% of deaths) on waiting-list for liver

292 transplantation, and that nine out of the ten patients who died from infections had a low TDPM  
293 at registration on transplantation list.

294 . *Study limitations.* The retrospective and monocentric design of the study exposed to the risk of  
295 bias. Nevertheless the characteristics of the study population were very similar to those of  
296 similar studies [17,19], and the proportion of missing data was less than 3%. Umbilicus-targeted  
297 CT scan could suffer from a lack of precision, particularly in the case of umbilical hernia,  
298 sacralisation of the L5 vertebrae, lumbar wedge fractures, and pronounced lordosis, frequent  
299 situations in the presence of ascites. However a lack of precision and a greater risk of error are  
300 also observed when analysing L3/L4-targeted images, in cases of degenerative bone diseases, i.e.  
301 vertebral osteoporosis, or lordosis related to ascites.

302 *In conclusion,* the transverse psoas muscle index measured by umbilicus-targeted CT scan is a  
303 predictive factor of mortality in cirrhotic patients on waiting-list for liver transplantation. This  
304 easy, cheap, reproducible, and reliable method is routinely feasible even by non-trained staff.  
305 Prospective randomized controlled trials should assess whether a dedicated nutritional  
306 intervention combining nutrition support and physical rehabilitation in liver cirrhosis patients  
307 with low muscle mass could improve the clinical outcome of liver cirrhosis patients before and  
308 after liver transplantation.

309  
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312

313 **Statement of authorship:**

314 AH, ML, EBJ and RT conceived and designed the study, carried out the collection of data,  
315 interpreted the data, performed the statistical analyses, and drafted the manuscript. PHD



316 designed the study, and carried out the collection of data. CZ, LL, and MR carried out the  
317 collection of data. KB and DG carried out the collection of data, and drafted the manuscript.

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**Table 1 – Liver cirrhosis patients’ baseline characteristics, at the time of their inscription on liver transplantation list (n=173).**

	Missing (n)	
Male / female – n (%)	0	135 (78) / 38 (22)
Age (year) – mean $\pm$ SD	0	54.7 $\pm$ 10.3
Body mass index – mean $\pm$ SD	0	26.2 $\pm$ 4.7
Etiology of cirrhosis – n (%)	0	
Alcohol		123 (71.1)
Metabolic		13 (7.5)
HBV		3 (1.7)
HCV		13 (7.5)
Others <sup>#</sup>		21 (12.1)
Duration of disease – mean $\pm$ SD		48 $\pm$ 56
Child-Pugh score – mean $\pm$ SD	4	10.1 $\pm$ 2.2
A – n (%)	0	17 (10)
B – n (%)		41 (24)
C – n (%)		115 (66)
Severe/ Refractory ascites	0	81 (47)
Plasma bilirubin ( $\mu$ mol/l) – mean $\pm$ SD	2	129 $\pm$ 54
Plasma albumin (g/l) – mean $\pm$ SD	2	31.5 $\pm$ 6.2
Prothrombin time (%) – mean $\pm$ SD	0	44 $\pm$ 19
MELD score – mean $\pm$ SD	0	21.2 $\pm$ 8.1
Plasma creatinine ( $\mu$ mol/l) – mean $\pm$ SD	0	85.5 $\pm$ 50.3
Plasma sodium (mmol/l) – mean $\pm$ SD	0	135 $\pm$ 5
APTI (mm/m) – mean $\pm$ SD	0	22.6 $\pm$ 3.6
TPTI (mm/m) – mean $\pm$ SD	0	17.0 $\pm$ 4.1

<sup>#</sup> Others included biliary cirrhosis, autoimmune hepatitis, sclerosing cholangitis, hemochromatosis. APTI, Axial Psoas Thickness Index; CI, confidence interval; HR, hazard ratio; MELD, Model for End-Stage Liver Disease; SD, standard deviations; TPTI, Transversal Psoas Thickness Index.

**Table 2 – Univariate analysis of variables associated with mortality on waiting-list for liver transplantation according to univariate Cox analysis (n=173).** Mortality was defined as the occurrence of death on waiting-list for liver transplantation; as previously published [14], patients removed from the transplantation waiting list because of the worsening of their liver cirrhosis were considered as deaths.

	Alive n=160	Dead n=13	HR [95% CI]	P-value
Male / female – n (%)	126 (78) / 34 (22)	9 (69) / 4 (31)	1.38 [0.77 – 2.49]	0.28
Age (year) – mean ± SD	54.4 ± 10.0	58.5 ± 6.0	1.06 [0.98 – 1.14]	0.13
Body mass index – mean ± SD	26.0 ± 4.6	27.7 ± 5.2	1.08 [0.96 – 1.22]	0.19
Etiology of cirrhosis – n (%)				
Alcohol	114 (71.3)	9 (69)	Reference	0.97
Metabolic	12 (7.5)	1 (8)	1.12 [0.14 – 8.96]	0.49
HBV	3 (1.9)	2 (15)	0.00 [0.00 – inf]	0.93
HCV	11 (6.9)	1 (8)	1.24 [0.26 – 5.81]	0.98
Others <sup>#</sup>	20 (12.5)		0.53 [0.07 – 4.24]	0.78
Duration of disease – mean ± SD	48 ± 57	39 ± 41	0.99 [0.98 – 1.00]	0.36
Child-Pugh score – mean ± SD	10 ± 2.2	10.6 ± 1.1	1.45 [1.08 – 1.96]	0.014
A – n (%)	17 (11)	0 (0)	-	-
B – n (%)	39 (24)	2 (15)	-	-
C – n (%)	104 (65)	11 (85)	-	-
Severe/ Refractory ascites	49 (30.6%)	8 (61.5%)	4.34 [1.31 – 14.30]	0.016
Plasma bilirubin (µmol/l) – mean ± SD	134.1 ± 159.0	68.4 ± 39.8	1.00 [0.99 – 1.01]	>0.99
Plasma albumin (g/l) – mean ± SD	31.5 ± 6.1	30.6 ± 6.4	0.95 [0.86 – 1.04]	0.29
Prothrombin time (%) – mean ± SD	44.3 ± 19.2	44.5 ± 10.2	0.97 [0.93 – 1.01]	0.11
MELD score – mean	21.2 ± 8.3	19.9 ± 3.3	1.12 [1.01 –	0.033

$\pm$ SD			1.25]	
Plasma creatinine ( $\mu\text{mol/l}$ ) – mean $\pm$ SD	83.8 $\pm$ 50.3	105.3 $\pm$ 46.7	1.02 [1.01 – 1.03]	<0.001
Plasma sodium (mmol/l) – mean $\pm$ SD	135 $\pm$ 5	133 $\pm$ 7	0.90 [0.81 – 0.99]	0.034
APTI (mm/m) – mean $\pm$ SD	22.6 $\pm$ 3.5	22.4 $\pm$ 3.6	0.91 [0.76 – 1.09]	0.30
TPTI (mm/m) – mean $\pm$ SD	17.1 $\pm$ 4.1	14.8 $\pm$ 3.8	0.84 [0.74 – 0.96]	0.009

# Others included biliary cirrhosis, autoimmune hepatitis, sclerosing cholangitis, hemochromatosis. APTI, Axial Psoas Thickness Index; CI, confidence interval; HR, hazard ratio; MELD, Model for End-Stage Liver Disease; SD, standard deviations; TPTI, Transversal Psoas Thickness Index.

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**Table 3 - Variables associated with mortality on liver transplantation list according to multivariate Cox analysis (n=173).** For continuous variables (Transversal Psoas Thickness Index (TPTI), Model for End-Stage Liver Disease (MELD) score, and plasma sodium), the hazard ratio (HR) are expressed for 1-point increase.

<b>Variables</b>	<b>HR</b>	<b>95% confidence interval</b>	<b>P-value</b>
TPTI per mm/m	0.87	0.76 – 0.99	0.034
MELD score per unit	1.10	0.99 – 1.22	0.08
Plasma sodium per mmol/l	0.94	0.85 – 1.04	0.26
Refractory ascites yes vs. no	2.93	0.83 – 10.30	0.094

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## Figures legends

**Figure 1 - Right psoas muscle diameters measured on a CT scan image targeted on the umbilicus.** Axial diameter of the psoas muscle (ADPM) is represented by the dotted line. Transversal diameter of the psoas muscle (TDPM) is represented by the full line.

**Figure 2 - Study flow chart.**

**Figure 3 - Predictive value of Transversal Psoas Thickness Index (TPTI) on mortality of liver cirrhosis patients on waiting-list for liver transplantation (n=173).** (A) Area under the receiver operating characteristic curves (AUC). A low TPTI is associated with increased mortality. AUC=0.66 [95% confidence interval, 0.51–0.80]. (B) Kaplan Meier curves indicating the probability of survival in patients with muscle mass loss (green line) or without muscle mass loss (blue line). Muscle mass loss was defined as Transversal Psoas Thickness Index (TPTI) <15.2 mm/m, as determined in (A); n=173; log rank test, P<0.01.

Figure 1

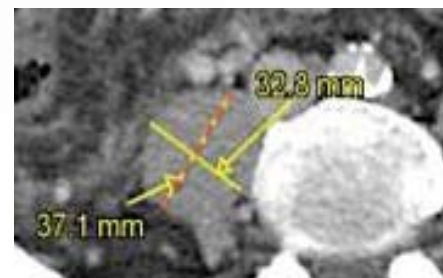
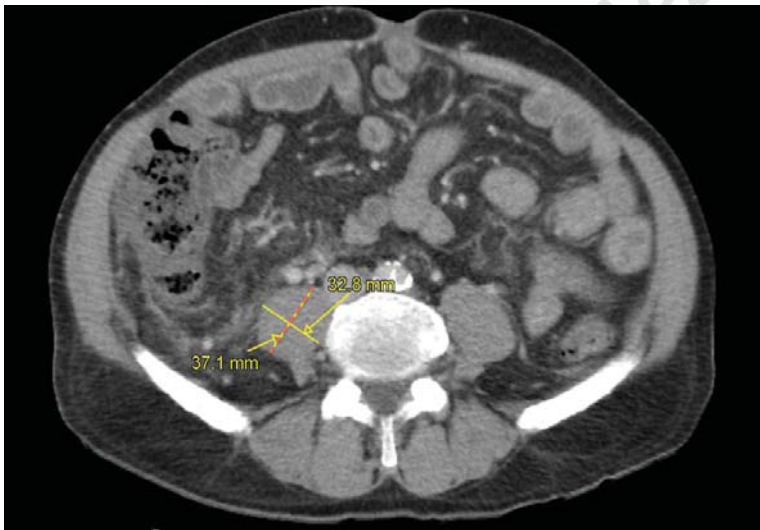
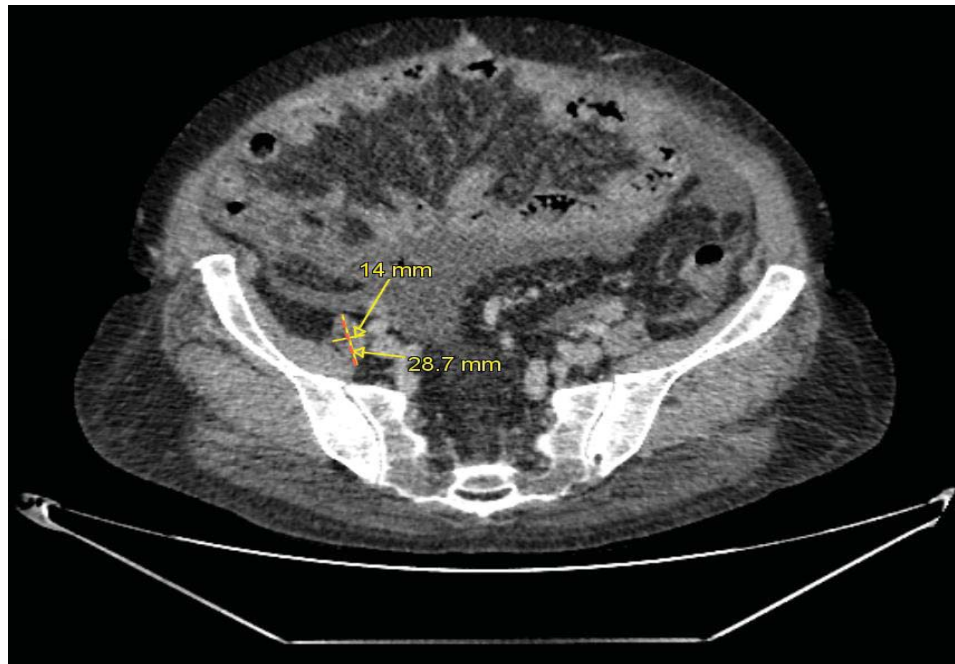


Figure 2

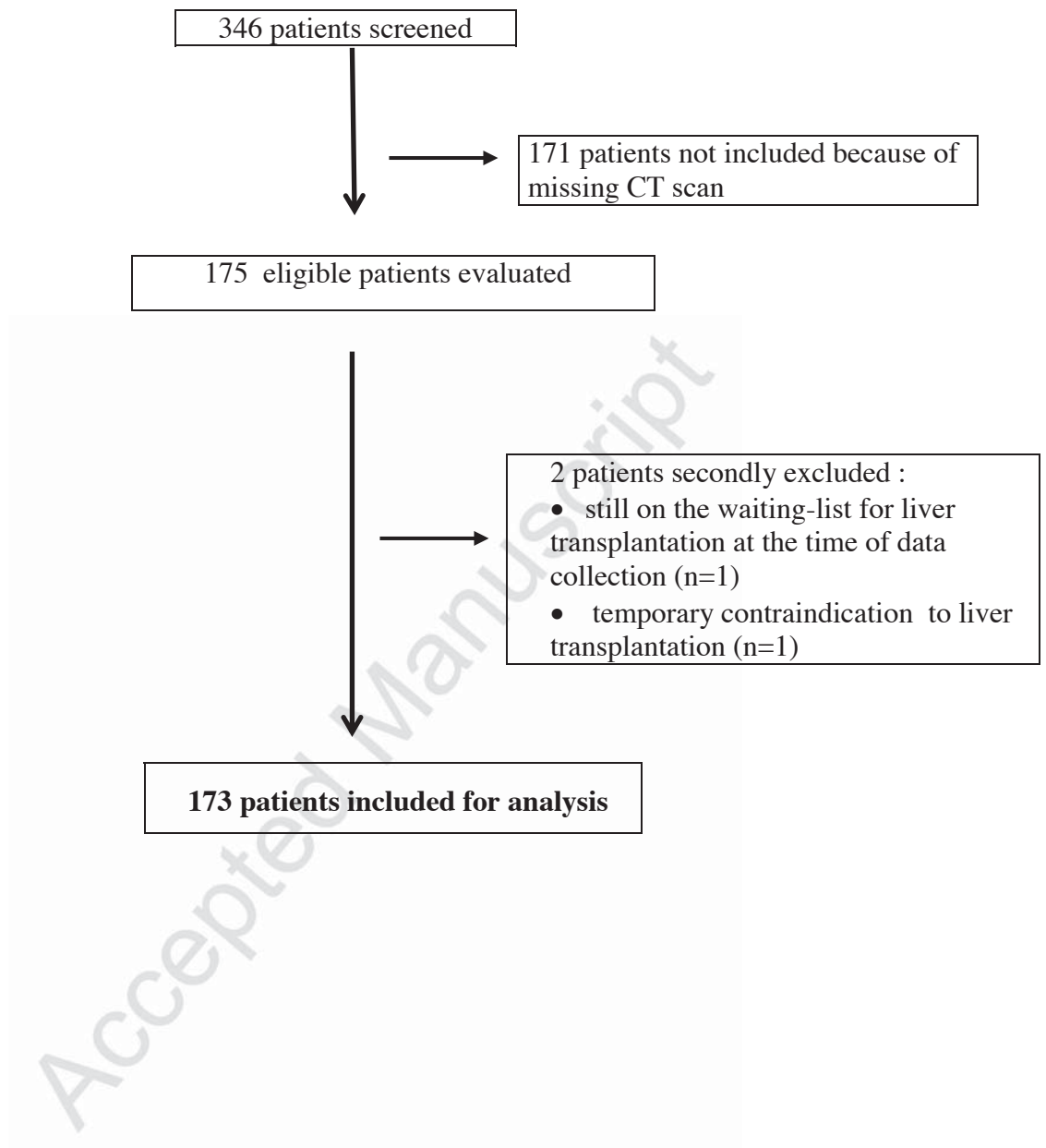
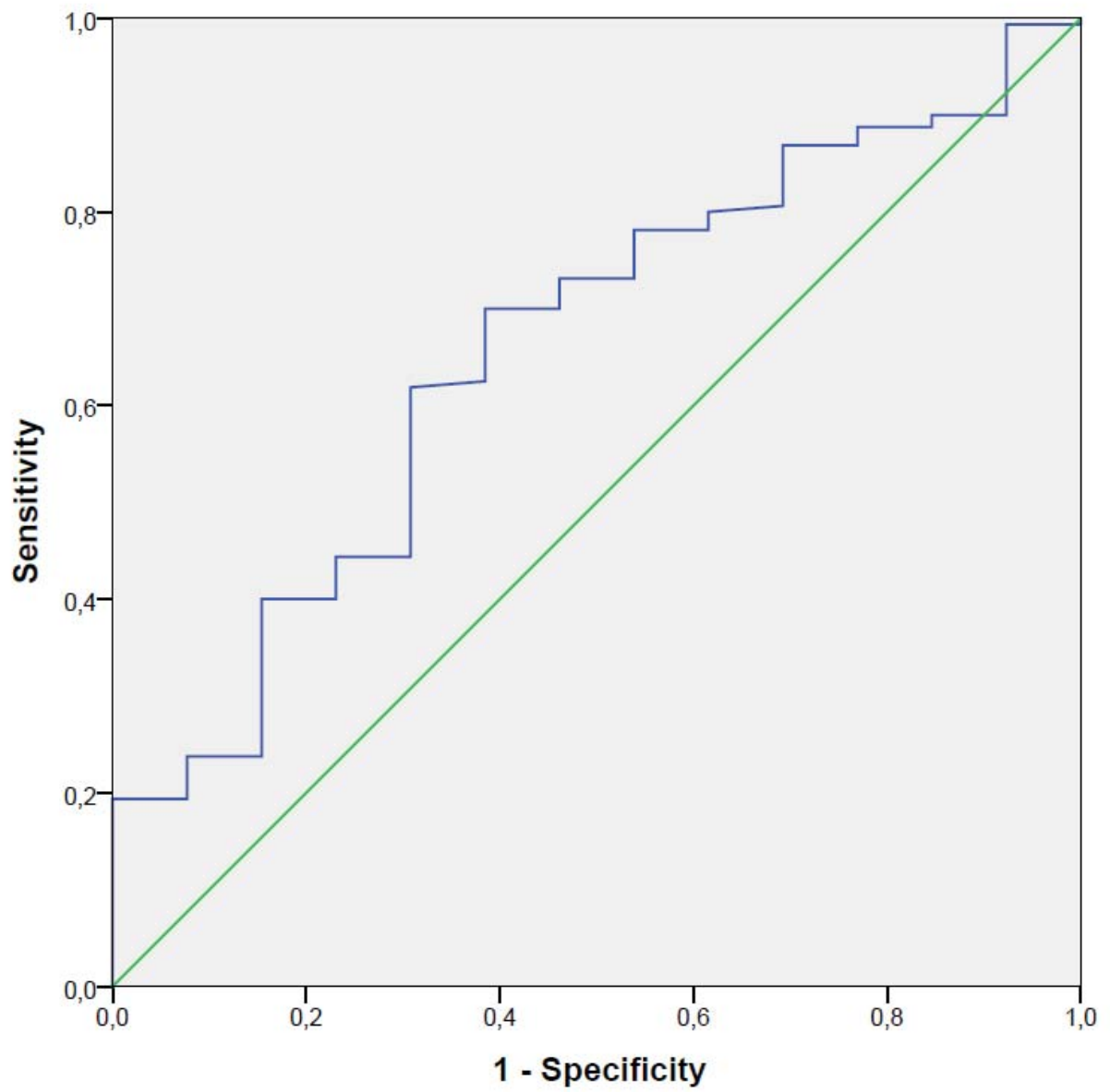


Figure 3

A



B

