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ORIGINAL ARTICLE

Can we refine the management of blunt liver trauma?

L. Barbier[a,d,*], M. Calmels[a], M. Lagadec[b], T. Gauss[c], P.-S. Abback[c], F. Cauchy[a], M. Ronot[b], O. Soubrane[a], C. Paugam-Burtz[c]

[a] HPB Surgery, hôpital Beaujon, université Paris 7 Diderot, DHU Unity, France
[b] Radiology, hôpital Beaujon, université Paris 7 Diderot, DHU Unity, France
[c] Department of Anesthesiology and Critical Care, hôpital Beaujon, université Paris 7 Diderot, DHU Unity, France
[d] Department of Digestive Surgery, hôpital Trousseau, université Rabelais, Tours, FHU SUPORT, France

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Summary
Aim: To describe the management of blunt liver injury and to study the potential relation between delayed complications, type of trauma mechanisms and liver lesions.
Patients and methods: This is a retrospective single center study including 116 consecutive patients admitted with blunt liver injury between 2007 and 2015.
Results: Initial CT-scan identified an active bleeding in 33 (28%) patients. AAST (American Association for the Surgery of Trauma) grade was 1 to 3 in 82 (71%) patients and equal to 5 in 15 (13%) patients. Eighty (69%) patients had NOM, with a success rate of 96%. Other abdominal organ lesions were associated to invasive initial management. A follow-up CT-scan was useful to detect hepatic and extra-hepatic complications (46 complications in 80 patients), even without clinical or biological abnormalities. Subsequent hepatic complications such as bleeding, pseudo aneurysms, biloma and biliary peritonitis developed in 15 patients and were associated with the severity of blunt liver injury according to AAST classification (3.7 ± 1.0 *vs.* 3.0 ± 1.1, $P = 0.010$). Total biliary complications occurred in 13 patients and were significantly more frequently observed in patients with injury of central segments 1, 4 and 9 (69% *vs.* 36%, $P = 0.033$).
Conclusions: Non-operative management is possible in most blunt liver injury with a success rate of 96%. A systematic CT-scan should be advocated during follow-up, especially when AAST grade is equal or superior to 3. Biliary complications should be suspected when lesions involve segments 1, 4 and 9.

Introduction

Non-operative management (NOM) is the reference treatment of blunt liver injuries (BLI) in hemodynamically stabilized patients [1—3]. NOM can be proposed in 65% to 85% of patients with BLI according to liver injury grading and associated lesions [2—4]. Computed Tomography-scan

* Corresponding author at: Department of HPB Surgery, hôpital Beaujon, 100, avenue du Général-Leclerc, 92110 Clichy-la-Garenne, France.
E-mail address: louisebarbier@hotmail.fr (L. Barbier).

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(CT-scan) is the corner stone in the assessment of BLI and the diagnostic modality of choice [5]. CT-scan allows the grading of the liver injury as established by the American Association for the Surgery of Trauma (AAST) [6] and the identification of associated lesions.

Failure of NOM is defined by the need for a delayed operation [3] and represents 5% [2] to 11% [7] of patients without early surgery. Systolic blood pressure on admission of 100 mmHg or less and the presence of other abdominal organ injury have been identified as independent factors of failure of NOM in AAST grades 4 and 5 BLI [3]. There is also no consensus on the monitoring of patients with NOM, specifically regarding the systematic imaging reassessment.

Biomechanical and modelization studies of livers subjected to injury have focused on the mechanisms of the lesions and the relationship with both liver anatomy and its attachment system [8—10]. However, there is no radio-anatomical study focusing on the relationship between the type of mechanism, the type of liver injury and the potential vascular and biliary complications.

The aims of this study were to describe the initial management of BLI and to study the potential relation between delayed complications, type of trauma mechanisms and liver lesions.

Patients and methods

Type of study

This retrospective study was conducted in the Beaujon Hospital a designated Trauma Center in the Paris region (France). Data from all consecutive patients with BLI who were admitted at the Trauma Center between 2007 and 2015 were collected from computerized clinical files. The trauma system and trauma management in the Paris region has been previously described [11].

Management of patients with trauma

Trauma patients were admitted in the resuscitation area after pre-alert from a physician-lead enhanced care team. The trauma leader, a senior intensivist, coordinated the trauma team including other specialists such as general surgeon, orthopedic surgeon, and radiologist. If the patient could be hemodynamically stabilized, a body CT-scan was performed. If not, the patient went directly to the dedicated operating room after minimum assessment included Chest X-Ray, pelvis X-Ray and FAST ultrasound. When there was no active hemorrhage or significant associated lesions, the NOM was the treatment of choice for BLI. In case of identified isolated active hemorrhage, interventional radiology with selective intra-arterial embolization was proposed, using either temporary agent such as Gel foam cubes or a permanent one such as micro coil depending on the type of vascular lesion and the selectivity of the catheterization. Indications for emergency laparotomy were uncontrolled hemorrhage or associated lesions such as perforation of hollow organs. Surgery was based on damage control laparotomy [12] with peri hepatic packing in case of massive venous hemorrhage involving hepatic veins, splenectomy, hollow organs sutures or stoma in case of perforation... Failure of NOM of BLI was defined as delayed surgery (but not interventional radiology) or death related to BLI during in-hospital stay [3].

CT-scan

The initial CT-scan was performed in hemodynamically stabilized patients and with the presence of the trauma leader and surgeons. Radiologists perform a body CT-scan according to trauma protocol with intravenous contrast enhancement and different time points: arterial phase or mixed arterio-portal phase and delayed phase. Liver lesions were described according to the recommendations using the AAST liver injury scale [6,13]. However, this scale has limitations and additional imaging findings were searched for: extension of the injury to the hepatic vessels, active bleeding, hemoperitoneum or hemoretroperitoneum, presence of a pseudo aneurysm, anatomic localization of the injury, and imaging findings of non-liver injuries (thorax, spleen, pancreas, bowel). The locations of the liver injuries that were specifically studied were: central segments (1, 4 and 9) that include the main biliary convergence, right and main portal scissures, frequently involved in case of acceleration or deceleration trauma, that respectively include the posterior and right biliary ducts on their path, and the right liver. CT-scan during the follow-up was performed according to the attending practitioner and depending on the initial lesions.

Definitions

Hemodynamic instability was defined [14] by mean arterial pressure less than 65 mm Hg and/or systolic pressure less than 90 mmHg, and the need for crystalloids and/or red blood cells transfusions. Hypothermia was defined by body temperature less than 35 °C, and acidosis by pH less than 7.36 [15]. Coagulopathy was defined by the association of low platelets count (less than 100 000/mm^3), low fibrinogen (less than 1 g/L), prothrombin time above 3 s, and increase in soluble fibrin or fibrinogen degradation products [16].

Statistical analysis

Qualitative variables were described as absolute numbers and percentages. Two groups of qualitative variables were compared using the Chi-2 test, with Yates' correction as appropriate and the Fischer's exact test according to the number of data and the distribution of the variable. Quantitative variables were described as mean and standard deviation of the mean. Two groups of quantitative variables were compared using the unpaired *t*-test or the Mann—Whitney test, according to the number of data.

Statistical analysis was performed using Microsoft® Excel® for Mac 2011 v 14.7.1 and Prism 7 for Mac OS X v 7.0b, GraphPad Software, Inc.

Ethics

Data for this study were extracted from a regional prospective trauma registry. The registry approval was obtained from the Institutional Review Board (Comité de Protection des Personnes, Paris VI) from the Advisory Committee for Information Processing in Health Research (CCTIRS, 11.305bis) and from the National Commission on Informatics and Liberties (CNIL, 911461). The structure of the database integrates algorithms for consistency and coherence. A central administrator assures the data monitoring. Missing data were collected anonymously from medical records.

The present study being an observational, non-interventional, retrospective study, neither informed consent nor approval of the ethics committee was required to use data from patients' records before 2017 according to French legislation.

Results

Description of the total cohort (Table 1 and Table 2)

During the study period, 116 patients were admitted at the Beaujon Hospital Trauma Center with BLI. Most of them were men ($n = 86$, 74%) and mean age was 31.5 ± 12.1 years old. At their admission (see Table 1), 35 (30%) patients presented with hemodynamic instability and 30 (26%) patients required transfusions of red blood cell packs. Overall, 46 (40%), 29 (25%) and 25 (22%) patients presented with acidosis, hypothermia and coagulopathy, respectively. Injury Scale Score was 32.1 ± 16.8 and SAPS was 34.8 ± 20.4. Motorcycle accidents were the most common type of trauma ($n = 38$, 33%), followed by car accident and falls from heights in the context of suicide ($n = 25$, 22% each). The mechanism of trauma was a direct shock in most cases ($n = 76$, 66%). Acceleration and deceleration mechanisms accounted for 31 (27%) patients.

Fifty-one (44%) patients had a FAST ultrasound in the resuscitation area: FAST was considered normal in 17 (33%), a minimal effusion was found in 29 (57%), and a major effusion in 5 (10%) patients. Twenty-one (41%) of patients with FAST were hemodynamically instable, and two of them had emergency surgery straight after FAST ultrasound.

CT-scan was performed after resuscitation in all but three patients. In these three patients emergency surgery was performed first. Findings of CT-scan are detailed in Table 2. The most common liver injury (88%) was parenchymal lesions

Table 1 Management of patients with BLI: comparison between NOM and invasive management. Invasive management group includes initial management with surgery and interventional radiology, and the patient who deceased at entrance.

	Total patients ($n = 116$)	Invasive management ($n = 36$)	NOM[a] ($n = 80$)	*P*[b]
Type of trauma				
Motorbike road traffic accident	38 (33%)	14 (39%)	24 (30%)	0.343
Fall from heights	25 (22%)	7 (19%)	18 (23%)	0.711
Car accident	25 (22%)	9 (25%)	16 (20%)	0.545
Equestrian accident	3 (4%)	0	3 (4%)	0.586
Fall	13 (11%)	3 (8%)	10 (13%)	0.510
Other	12 (10%)			
Mechanism of trauma				
Direct shock	76 (66%)	28 (78%)	48 (60%)	0.062
Acceleration/deceleration	31 (27%)	7 (19%)	24 (30%)	0.234
Crushing	6 (5%)	1 (3%)	5 (6%)	0.435
Other	3 (3%)			
State at initial presentation				
Hemodynamic instability	35 (30%)	20 (56%)	15 (19%)	**<0.001**
RBC[c] transfusions (yes)	30 (26%)	21 (58%)	9(11%)	**<0.001**
Number of RBC packs	4.8 ± 4.1	5.5 ± 4.7	3.5 ± 1.7	0.448
Fluid expansion	48 (41%)	24 (67%)	24 (30%)	**<0.001**
Norepinephrine	41 (35%)	20 (56%)	21 (26%)	**0.002**
Acidosis	46 (40%)	22 (61%)	24 (30%)	**0.002**
Hypothermia	29 (25%)	14 (39%)	15 (19%)	**0.021**
Coagulopathy	25 (22%)	14 (39%)	11 (14%)	**0.002**
Hemorrhagic shock	24 (21%)	17 (47%)	7 (9%)	**<0.001**
ISS[d]	32.1 ± 16.8	36.6 ± 20.0	31.4 ± 14.9	0.337
SAPS[e]	34.8 ± 20.4	41.0 ± 23.0	31.6 ± 18.2	**0.043**
CT-scan lesions				
Active bleeding	33 (28%)	18 (50%)	15 (19%)	**<0.001**
AAST[f] classification	3.1 ± 1.1	3.5 ± 1.2	2.9 ± 1.0	**0.001**
Subsequent management				
Surgery	11 (9%)	8 (22%)	3 (4%)	**0.002**
Interventional radiology	9 (8%)	5 (14%)	4 (5%)	**0.100**
Surgery *OR* interventional radiology	20 (17%)	13 (36%)	7 (9%)	**<0.001**
Intra hospital death	9 (8%)	6 (17%)	3 (4%)	**0.020**

[a] NOM: non operative management.
[b] Comparison between invasive group and NOM group.
[c] RBC: red blood cells.
[d] Injury severity score.
[e] Simplified acute physiology score.
[f] American Association for the Surgery of Trauma.
Quantitative data are expressed as mean ± standard deviation. *P* values <0.05 were statisitically significant. *P* with significant values are in bold.

Table 2 Features of liver trauma and associated lesions on initial CT-scan (n = 116).

Type of lesions	Localization/size	*N*	%
Hematoma		54	46
	Sub-capsular	27	23
	Intraparenchymal	27	23
	<1 cm	4	7
	1–3 cm	11	20
	>3 cm	39	72
Active arterial bleeding		33	28
Major hepatic venous injury		0	0
Parenchymal liver injury	Lacerations	102	88
	<1 cm	0	0
	1 to 3 cm	18	17
	>3 cm	89	76
	Contusions	5	4
	Segments 1/4/9	46	43
	Right liver	94	88
	Left lobe	15	14
	Along falciform ligament	2	2
Area nuda injury		44	38
Vascular injury		66	57
	Right portal fissure/right hepatic vein/right portal vein/right hepatic artery	51	77
	Main portal fissure/median hepatic vein/segments 1/4	11	17
	Left portal vein/left hepatic vein/left hepatic artery	9	14
Right adrenal gland injury		43	37
Hepatic hilum injury		26	22
Biliary injury		7	6
	Including gallbladder	3	3
Pseudo aneurysm		6	5
Periportal infiltration		30	26
Flat inferior vena cava		6	5
Hemoperitoneum		33	28
AAST grade	1	10	9
	2	22	19
	3	50	43
	4	19	16
	5	15	13
Pneumoperitoneum		1	1
Other associated thoraco-abdominal lesions		94	81
	Spleen	12	13
	Hollow organ	3	3
	Thorax (hemothorax/pneumothorax/rib fractures)	81	86

with lacerations and contusions. An active arterial bleeding was identified in 33 (28%) patients, and pseudo aneurysms in 6 (5%) patients. There was no hepatic vein injury. Most of the vascular injuries were located in the right liver (n = 51, 77%). Most of the patients had 1 to 3 AAST grade (n = 82, 71%), and 15 (13%) patients had grade 5 lesions. Associated lesions were present in 94 (81%) patients, predominantly thoracic injuries.

Initial management (Fig. 1 and Table 1)

Fig. 1 describes the initial management of the 116 patients: 80 (69%) patients were hemodynamically stabilized and had NOM, while 35 (30%) patients had an invasive management with surgery and/or interventional radiology. One patient deceased from associated cerebral lesions after initial assessment with FAST ultrasound and CT-scan.

Indications for emergency laparotomy (n = 14, 12%) included: massive hepatic bleeding (n = 7), associated spleen trauma (n = 5), associated perforation of a hollow organ (n = 9). Totally, emergency laparotomy was performed for an isolated BLI in only 2 patients. Interventional radiology was performed in 27 patients, and in combination with surgery in 6 patients.

As expected, patients with initial invasive management (see Table 1) were more frequently hemodynamically instable with acidosis, coagulopathy and hypothermia at admission. They required more often transfusions, and the

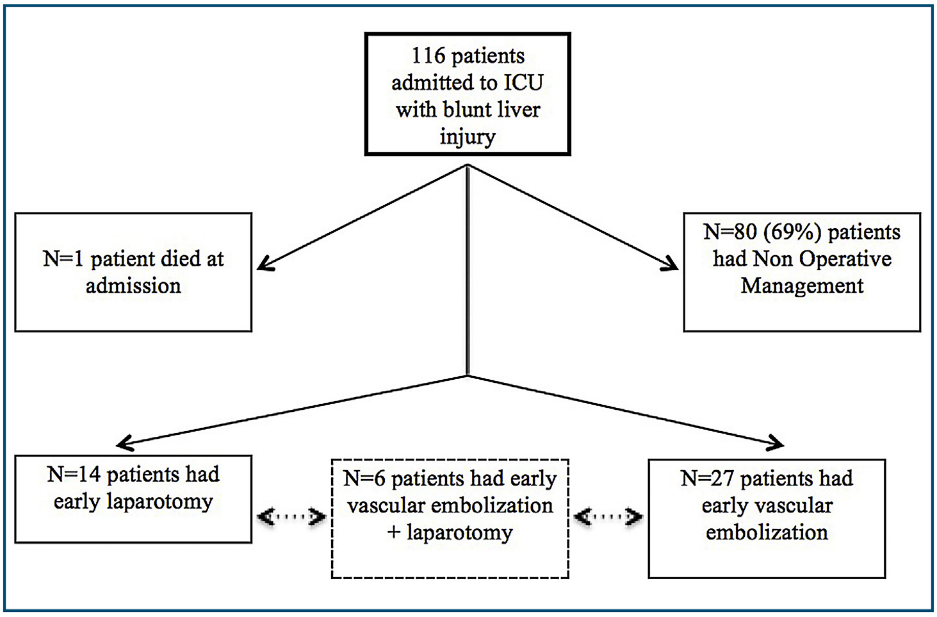

Figure 1. Initial management of the 116 with BLU admitted at the intensive care unit. ICU: intensive care unit.

SAPS was higher. There was more often active bleeding at the initial CT-scan and the AAST liver injury grade was higher.

Follow-up: subsequent management and complications (Table 1 and Table 3)

Overall, 20 (17%) patients required further interventional radiology and/or surgery (see Table 1), which was more frequent in the initial invasive management group *vs.* NOM group (36% *vs.* 9%, $P < 0.001$).

A total of 55 (47%) patients presented complications (Table 3). The most frequent complications were pulmonary complications (pleural effusion, pneumopathy, pulmonary embolism). Iterative bleeding and pseudo aneurysms were found in 5 (4%) patients each, and biliary complications in 7 (6%) patients. Mean total in-hospital stay was 29 ± 52 days.

In-hospital mortality rate was 4% ($n = 3$) in the NOM group and 17% ($n = 6$) in the invasive management group. Causes of death were as follows: associated neurological trauma ($n = 4$), respiratory distress in patients with thorax trauma ($n = 2$), uncontrollable hemorrhage arising from thorax, abdomen and/or pelvis ($n = 3$). Six of the deceased patients had management with early laparotomy and/or interventional radiology. The death occurred at a mean of 35 ± 109 days following the trauma. All patients but one who deceased during in-hospital stay had a SAPS (simplified acute physiology score) score superior to 60 at initial management.

Totally, NOM was a success in 77 (96%) patients, with three patients who required delayed surgery after NOM trial (see Table 1). Regarding the three patients with failure of NOM, none of them had hemorrhagic shock or hemodynamic instability at initial presentation, and none of them required initial red blood cells transfusions. All of them presented lesions of the right liver and the central segments (1, 4 and 9). Only one of them did not have other organ associated lesions. A delayed surgical intervention was required in one patient for hemorrhage and in two patients for biloma/biliary peritonitis. Causes of death of the three patients in the NOM group were not related to BLI (and were not considered as a failure of NOM, according to the definition [3]): neurological trauma ($n = 1$), and thoracic trauma ($n = 2$).

Table 3 Complications during hospitalization.

Complications	*N*	%
Total	55	47
Hemorrhagic complications		
Bleeding	5	4
Pseudo aneurysm	5	4
Red blood cells transfusions after initial management	12	10
Requirement for interventional radiology	5	4
Biliary complications	7	6
Biloma	3	3
Biliary peritonitis	4	3
Hemobilia	0	0
Intrahepatic abscess/collection	2	2
Hepatic necrosis	1	1
Acute coronary syndrome	2	2
Pulmonary complications		
Pleural effusion requiring drainage	16	14
Pneumopathy	17	15
Pulmonary embolism	5	4

CT-scan during the follow-up

A CT-scan was performed during the in-hospital stay for 80 (69%) patients. The CT-scan was performed systematically in 46 (58%) patients, and based on clinical or biological abnormalities in 34 (42%). Totally, the follow-up CT-scan detected 33 (41%) complications and 4 (5%) hepatic vein thrombi. Systematic CT-scan detected 7 (15% of patients with systematic CT-scan) hepatic complications (2 pseudo aneurysms, 2 biloma and 3 hepatic vein thrombi) and 13 (28%

Table 4 Factors associated with total biliary complications (univariate analysis).

	Biliary complications (*N* = 13)	No biliary complications (*N* = 103)	*P*
Initial assessment			
Hemodynamic instability	5 (38%)	30 (29%)	0.528
SAPS[a]	29.5 ± 14.6	35.5 ± 21.0	0.476
Mechanism of trauma			
Direct shock	10 (77%)	66 (64%)	0.538
Acceleration/deceleration	3 (23%)	28 (27%)	>0.999
BLI[b]			
AAST score	3.4 ± 1.0	3.0 ± 1.1	0.295
Laceration > 3 cm	11 (85%)	78 (76%)	0.730
Location of liver injury			
Segments 1/4/9	9 (69%)	37 (36%)	**0.033**
Right portal scissure	6 (46%)	45 (44%)	>0.999
Main portal scissure	2 (15%)	9 (9%)	0.356
Right liver	12 (92%)	82 (80%)	0.528
Percutaneous TAE[c]	4 (31%)	28 (27%)	0.751

[a] SAPS: simplified acute physiology score.
[b] BLI: blunt liver injury.
[c] TAE: Trans arterial embolization, during initial management or subsequent in-hospital stay. *P* values <0.05 were statistically significant. *P* with significant values are in bold.

of patients with systematic CT-scan) thoracic complications (pleural effusion and pneumopathy).

Risk factors for hepatic and biliary complications

Subsequent hepatic complications (bleeding, pseudo aneurysms, biloma and biliary peritonitis) that developed during follow-up arose in a total of 15 patients. Initial AAST liver injury-grade was higher in patients who developed hepatic complications: 3.7 ± 1.0 *vs.* 3.0 ± 1.1 (*P* = 0.010); all patients but one who developed hepatic complications had AAST liver injury grade equal or superior to 3.

Total biliary complications (at initial assessment and during follow-up) included biloma, biliary peritonitis and gallbladder injury and were present in 13 patients. The only factor associated with total biliary complications was injury of segments 1/4/9 (69% *vs.* 36%, *P* = 0.033, see Table 4).

Discussion

Our findings confirm that NOM is feasible in most patients with BLI. The rate of 69% in the present study is consistent with the largest series of the literature [2—4], as is its success rate of 96% [3]. Patients most likely to undergo initial invasive management presented with more hemodynamic instability and higher SAPS. Associated lesions, such as spleen trauma and perforation of hollow organs were responsible for most indications of emergency surgery. Other abdominal organ injury has as well been found to be associated with failure of NOM [3]. Furthermore, neurological and thoracic lesions were considered as the cause of death in 6 of the 9 patients who died at hospital, with uncontrollable hemorrhage accounting for the three remaining deaths.

Classification of BLI according to the AAST classification [6] is a standardized tool for all radiologists and clinicians. In this study, AAST grade was associated with initial invasive management and development of biliary and vascular hepatic complications during follow-up. Systematic CT-scan during in-hospital stay after BLI and spleen trauma has been questioned in children [17] and in adults [18]. In the present study, although more complications were diagnosed on follow-up CT-scan when clinical or biological abnormalities were present, a systematic CT-scan detected hepatic and thoracic complications in respectively 15% and 28% of the patients. We confirm the results of Osterballe et al. [18], who showed that hepatic pseudo aneurysms develop in 4% of the BLI patients, and recommended systematic CT-scan during follow-up.

The only factor associated with biliary complications was the injury of central segments of the liver, *i.e.* segments 1, 4 and 9. Unlike Yuan et al. [19], we did not identify an association between trans arterial embolization or high-grade liver injury and major bile leak. Segments 1, 4 and 9 are the segments in contact with the biliary confluence; if injured, a biloma or biliary peritonitis should be suspected and searched for systematically with imaging.

The main limit of this study is our failure to identify more associations between the mechanism of trauma, the detailed anatomical location of BLI and the subsequent complications. The retrospective nature of the study and the complexity of liver injuries mechanisms may be responsible for a certain lack of power and the incapacity to study complex mechanisms. Nonetheless, our results confirmed that NOM was possible in most BLI with a success rate of 96%, and that a systematic CT-scan should be advocated during follow-up, especially when AAST grade is equal or superior to 3. Biliary complications should always be suspected when lesions involve central liver segments.

Conclusion

This study demonstrated that NOM was feasible in 69% of BLI patients with a success rate of 96%. Associated organ lesions accounted for most of emergency surgery. We recommend a systematic follow-up CT-scan that allows detection of both hepatic and thoracic complications, in particular when AAST is equal or superior to 3. A specific attention must be paid to injuries to hepatic segments 1, 4 and 9 were associated with biliary complications.

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Disclosure of interest

The authors declare that they have no competing interest.

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