Endogenous factors of liver injuries
Forensic aspects.

Doctoral (PhD) thesis

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2020

Introduction

Injury mechanisms are among the corner stones of forensic medicine. According to the No. 16 protocol of the National Forensic Medicine Institute, the forensic expert has to assess the anatomical characteristics of the injured region, the size of the impact strength, and also the presence of diseases has to be taken into account. The protocoll however, does not give a guideline for the assessment of these factors. In the present legal envirorment, it is more and more an expectation from the practical perspective, that the forensic statements should be based on established scientific facts, which could be referenced. The knowledge of the mechanical background of injuries, biomechanical properties of the human body and tissues can provide the basis for assessing the injury mechanisms.

The liver is among the parenchymal organs with the highest injury frequency, and there is plentifull scientific literature avaliable about it's injury mechanism and biomechanical properities. There is however very limited data avaliable about the effect of the very frequent pathological alterations on liver vulnerability, and the conclusions are shallow and contradictory. The goal of my research was to examine to effect of steatosis and fibrosis on the mechanical vulnerability of the liver.

Aims

The aim of the thesis was the investigation of the effects of histological changes on liver vulnerablitiy in an objective and reproducable manner. My aim was to assess, whether certain histological changes have any influence on blunt force vulnerability of liver, an if they do, in what direction and what extent.

I was searching answers to the following questions:

1. Are there any connection between the liver weight and dimensons, and the hystological picture?
2. The correlation of liver injury frequency with hystological picture and other factors.
3. What kind of reproducible, obcjective measurment method can be established for the examination of the vulnerablity of liver tissues.
4. What connection can be proved between the hystological changes of liver and the injuries porduced under standardized circumstances?

Biomechanical examinations

A force gauge placed on an automatic motorized teststand is usually used in biomechanical measuremets. In these cases, the test stand moves the force gauge with a certain speed, and the force gauge registers the force and the displacement. With these method, it is possible to examine pressure by simulating compression, and it is also possible to examine tension/tearing. In the latter case a sandardised sized and shaped /usually „dog-bone" shaped/ tissue sample is teared with pulling. Other methods are the drop or slide tests, in which cases an object with a certain weight are dropped down from a certain height onto the organ. This methods simulates the impact type force best, so it is suited to determine the minimal size of force which can cause injury. Hovewer it is incapable to depict the force and displacement curve.

The injuries of the liver and its biomchanical properities.

The liver injuries have an emphasized role in forensic medicine among the internal organs due to their frequency and severe consequence. Liver injuries can be caused by penetrating injuries (typically by shot or stab wounds), or by blunt forces. Liver injuries can be caused not only by penetration or compression, but also by acceleration or decelaration. From a biomechanical perspective, the liver is a nonlinear elastic, transversly isotropic organ. The biomechanical properities are defined by the capsule, the parenchyma and the blood. There is only a very limited data avaliable about how the structural changes are affecting the biomechanical properties of the organ. These experiment were mostly targeted to develop diagnostic methods, and had not forensic considerations.

Analysis of factors influencing liver injuries.

In the developement of liver injuries, apart from the type, size and direction of the force, the wight, dimension, tissue structure and other tissues with defending effect (fat tissue, capsule) also can play a part. To assess these factors, data from autopsies was statistically analysed.

The correlation between sturctural changes and liver wight and dimansions.

I measured the liver weight and dimensions during 213 autopsies, than i analysed their correlations with hystological changes. The samples were classified according the following classification criteries used in the scientific literature:

1. group: intact without steatosis or fibroris („intact")
2. group: minimal steatosis, which affect only a few – less than 5 % liver cells ("very mild")

3. group: mild steatosis, wich affect less than third of liver cells („mild”)
4. group: moderate steatosis, affecting 33-66 % of liver cells („moderate”)
5. group: severe steatosis, affecting more than 66 % of liver cells („severe”)
6. group fibrosis without steatosis („fibrosis”)
7. group: fibrosis with the presence of steatosis („steatofibrosis”)
8. group: cirrhosis withour steatosis („cirrhosis”)
9. group: cirrhosis with the presence of steatosis („steatocirrhosis”)

IBM SPSS (ver 26) software was used for statistical analysis.

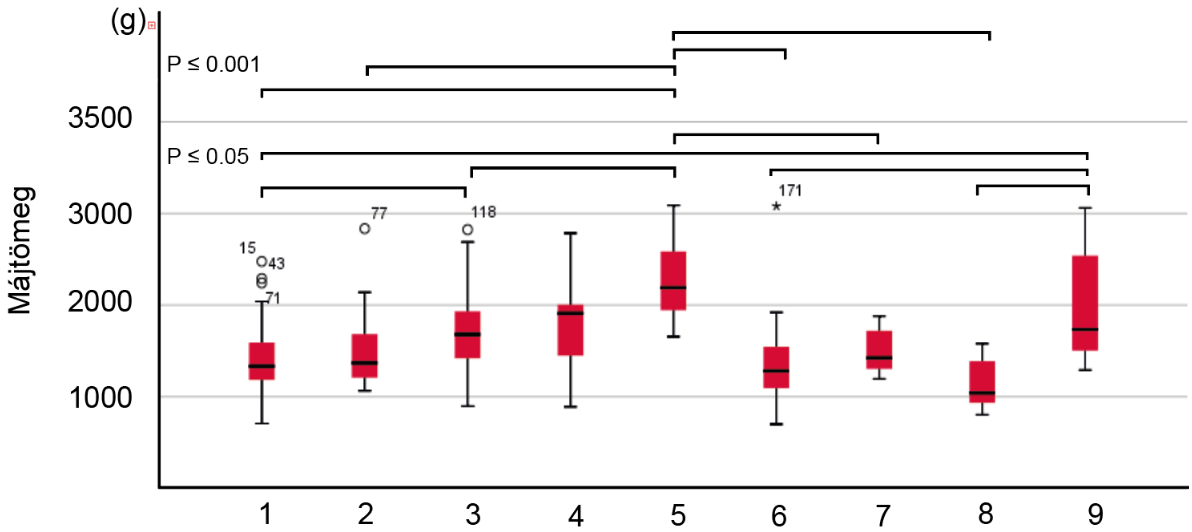
The correlation between age, body height and liver weight.

Significant correlation was found between the body height and liver weight ($p<0.000$, $R2=0.252$). Stronger correlation was found between the body height and liver weight by exmaining only the organs without hystological change ($p<0.000$, $R2=0.450$).

Significant correlation was found between the age and liver weight in case when all samples were analysed ($p<0.000$, $R2=0.081$). If only the samples belonging to the intact (1) group were examined, than no signicant correlation could be established. The multivariate regression analysis of the whole data set showed signifacant correlation between the liver weight and combined body height/age ($p<0,000$; $R^2=0.252$).

The correlation betwwen liver weight and histological appearance.

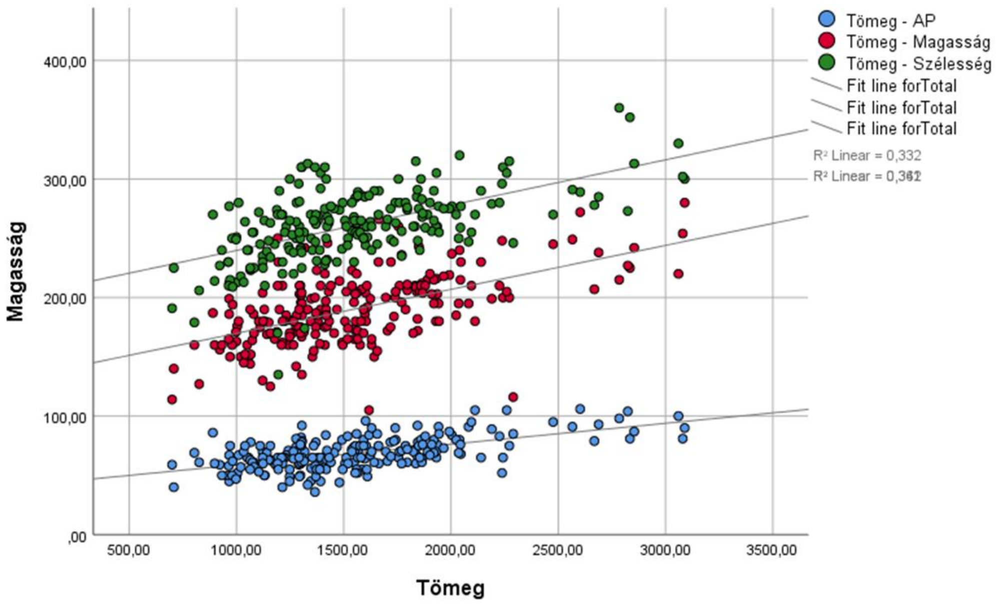
The liver weight was significantly larger in samples showing mild (3), moderate (4), severe (5) steatosis and steatocirrhosis (9) than in intact (1) samples ($p=0.03$, $p=0.05$, $p<0.000$, $p=0.005$).



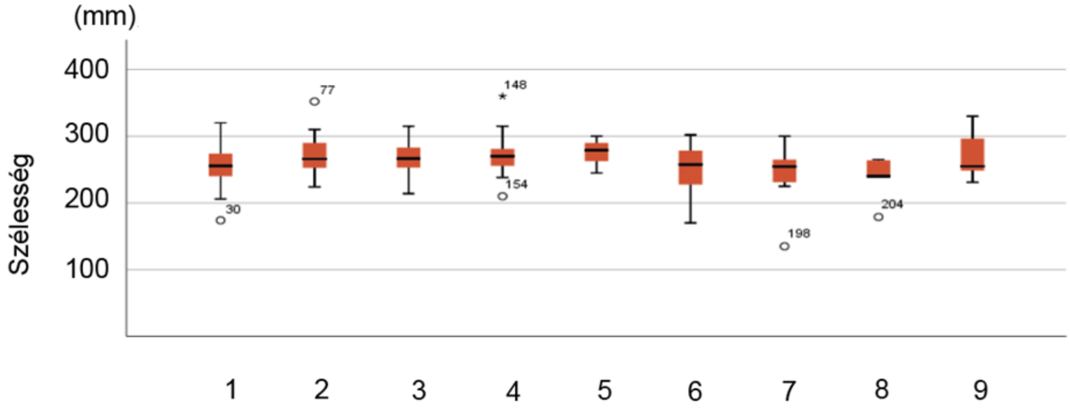
If body height was also taken into account, than the liver size was significantly larger in samples showing mild (3), moderate (4), severe (5) steatosis and steatocirrhosis (9) than in intact (1) samples (p<0.000, p=0.007, p<0.000, p<0.000).

The analysis of connection between liver weight and dimensions

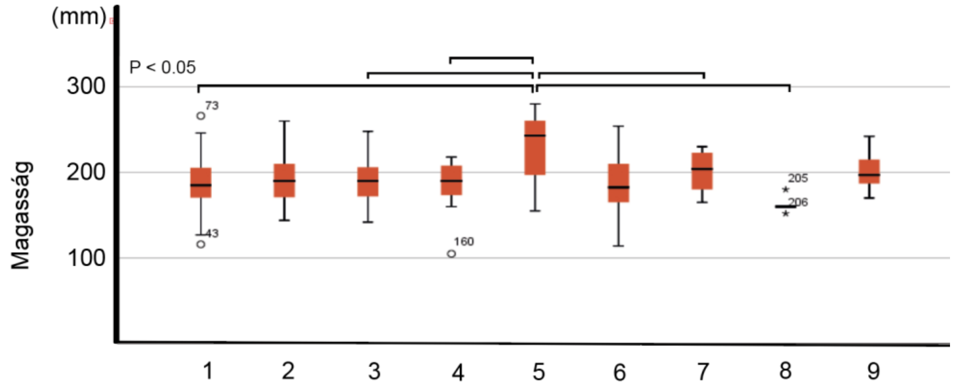
There was significant correlation found between the liver weight and all parameters of dimension (height, width, and A-P diameter), (p<0.000, R2= 0.341, 0.332, 0.361).



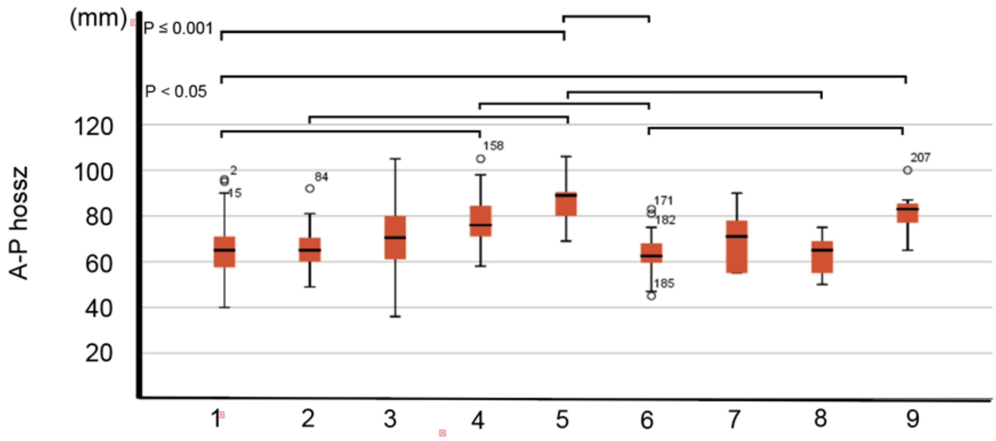
By analyzing the correlation of certain hystological changes with liver dimensons, it was seen that the liver width (transverse diameter) does not significantly different in the histological groups.



Significant difference in height (vertical diameter) was found between the severe steatosis (5) and intact (1), mild steatosis (3), moderate steatosis (4), fibrosis (6) and cirrhosis (8) gorups (p=0.19, 0.34, 0.56, 0.20, 0.005).



The antero-posterior diameter was significantly different in several steatotic groups.



Analysis of connection between abdominal fat tissue and the structural changes of liver.

The thickness of abdominal fat tissue was compared with liver weight, its correlation with hystological changes was analysed. There was significant correlation between the liver weight and fat tissue thickness ($p<0.000$, $R2=0.100$), but there was no significant correlation between the fat tissue thickness and hystology.

Frequency of liver injuries in autopsy cases.

I've analysed all those forensic autopsy reports of the Forensic Medicine department between 2007 and 2009, where the whole body suffered large blunt force (acceleration, decelaration). These forces occured typically durin fall from heights and traffic accidents. There was 2767 forensic autopsies in the department, from which 500 cases fit the criteries (18.1 % of all cases).

Analysis of the role of liver weight in injury occurance.

Th liver weight was recorded in the autopsy reports in 480 from the 500 cases. Average liver weight was 1585 g (min-max: 534-8000 g, SD± 549.4) The organs were categorized into 6 gorup by their weight, and the groups were compared by tthe injury frequency.

	Weight (g)	No of cases (db)	Intact (db)	Injured (db)	Rate of injured organs (%)
1	500-999	22	11	11	50
2	1000-1499	220	141	79	35.9
3	1500-1999	178	112	66	37.1
4	2000-2499	41	30	11	26.8
5	2500-2999	10	8	2	20
6	above 3000	9	4	5	55
	all	480	306	174	36,3

There was no significant correlation between the liver weight and probability of injury ($p=0.925$).

The same analysis was made in case of falls from heights, since decelaration dominates in these cases, and circumscribed impact type injuries does not really have to take into account usually.

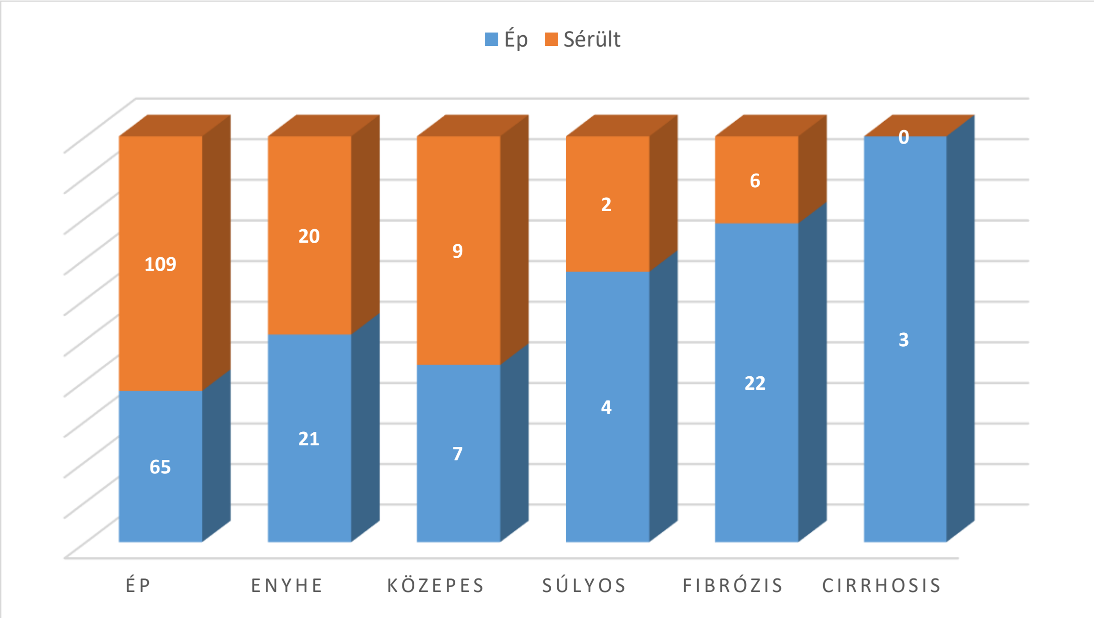
	Weight (g)	No of cases (db)	Intact (db)	Injured (db)	Rate of injured organs (%)
1	500-999	6	3	3	50
2	1000-1499	47	24	23	48.9
3	1500-1999	34	24	10	29.4
4	2000-2499	7	4	3	42.8
5	2500-2999	1	1	0	0
6	above 3000	1	1	0	0
	all	96	57	39	40,1

There was no significant correlation between the liver weight and probability of injury in case of fall from heights either ($p=0.215$).

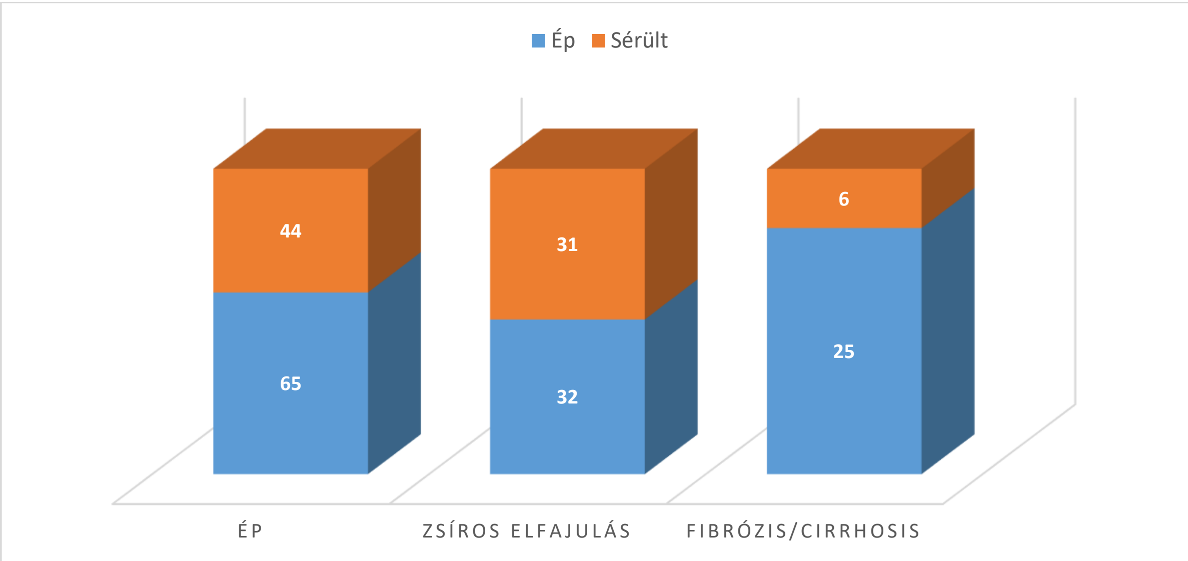
Analysis of the connection of injury rate and hystological changes.

I analysed the correlation between hystological changes and liver injury rate. I have reevaluated the liver hystology in 203 autposies, and i've categorized these into the following hystological groups:

1. group: intact, without steatosis or fibrosis („intact")
2. group: mild steatosis, wich affect less than third of liver cells („mild")
3. group: moderate steatosis, affectng 33-66 % of liver cells („moderate")
4. group: severe steatosis, affectng more than 66 % of liver cells („severe")
5. group fibrosis with or without steatosis („fibrosis")
6. group: cirrhosis with or without steatosis („cirrhosis")



Rate of injury in the different hystological groups



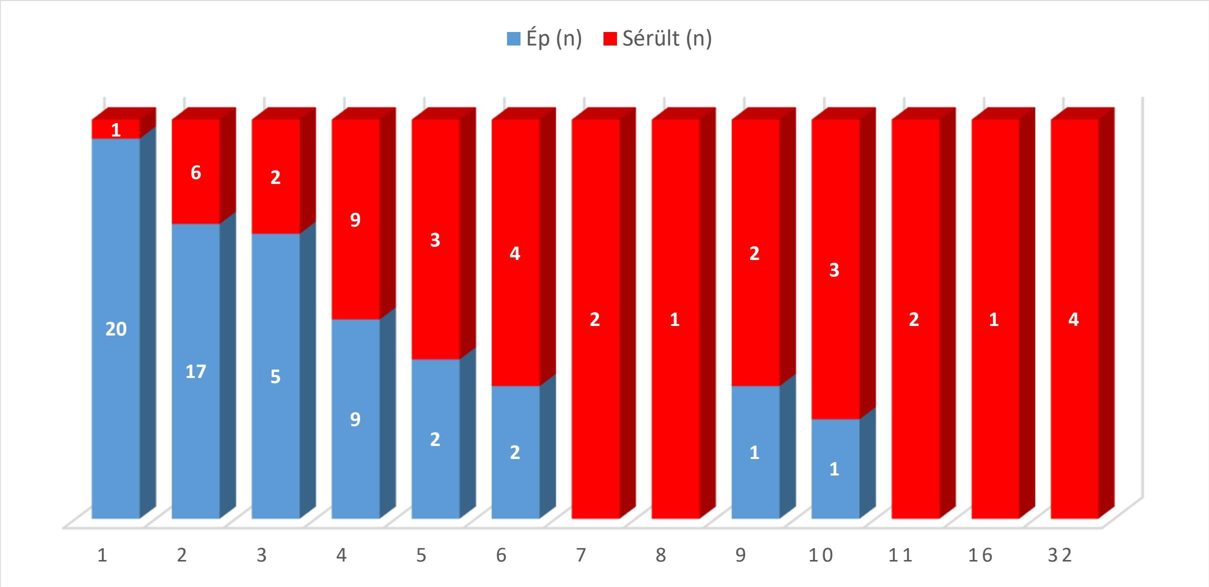
Rate of injury in combined hystological groups

There was no significant correlation between hystology and injury rate (p=0.096).

It could be stated by comparing the different groups, that injury rate is significantly lower in presence of cirrhosis and fibrosis, than in case of intact and steatotic groups (p=0.035, p=0.007). There was no significant difference in injury rate between the intact and steatotic groups (p=0.247).

The role of the size of the force in injury occurance

The height essentially defines the size of force in case of falls from heights, so i used the cases of falls from heights cases to analyse the connection between the size of the force and liver injury rate. Because of practical reasons, not the metric height data, but the storey number was used for comparison, because the authorities usally shared only this information and not the height in meters.



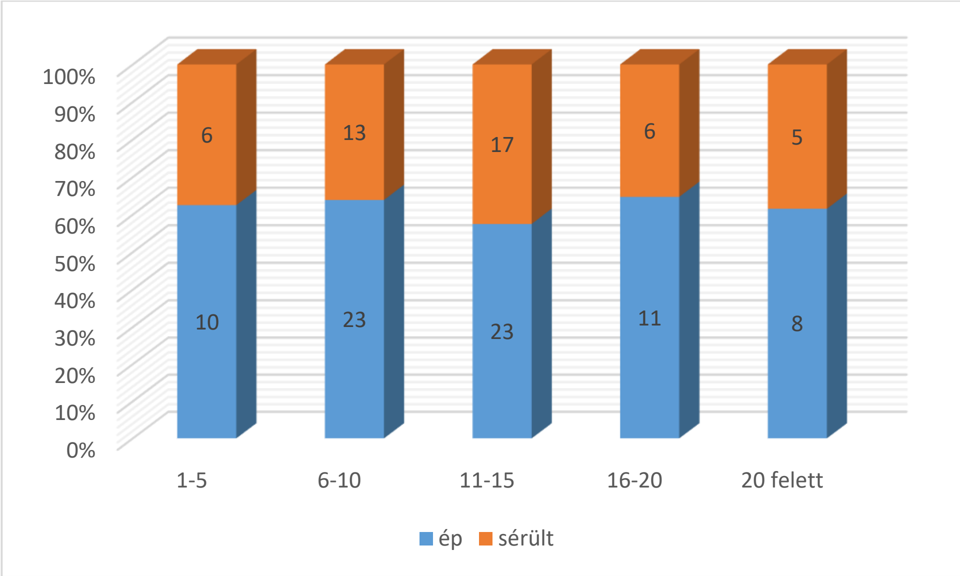
The story number and injury rate

The injury rate significantly correlated with the storey number (p=0.014).

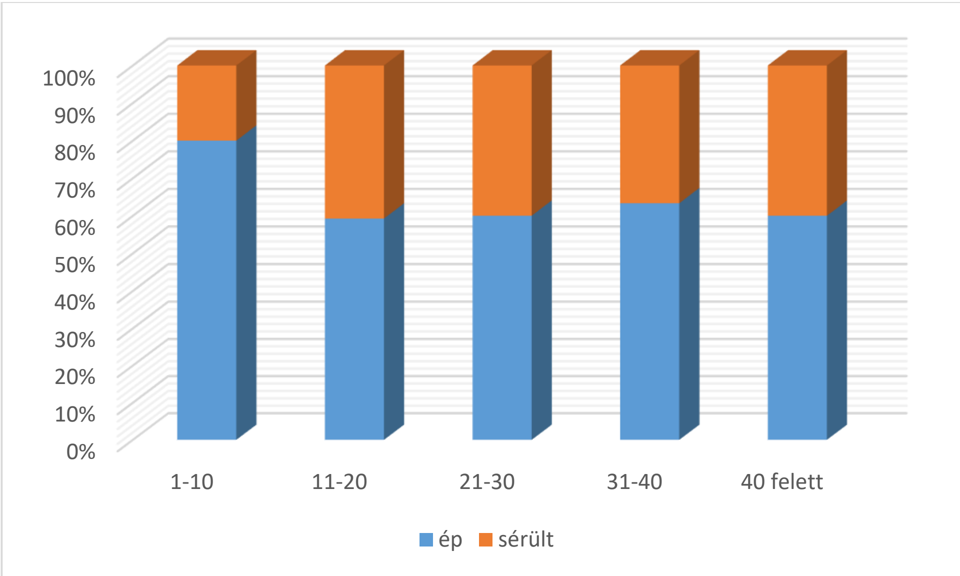
The role of the thoracical and abdominal fat tissue

To analyse the role of thoracical and abdominal fat tissue, i've analysed 75 autposy cases of large blunt force injury.

The average thickness of thoracical fat tissue was 13.1 mm (2-39, SD± 6.9), the thickness of abdominal fat tissue was 30.9 mm (5-100, SD±16.0).



The thoracical fat tissue thickness (mm) and injury rate.



The abdominal fat tissue thickness (mm) and injury rate.

The statistical analysis of the measured data showed no significant difference in injury rate in cases of thoracical and abdominal fat tissue thickness ($p=0.820$, ill $p=0.465$).

Exmination of liver vulnerability

My goal of research was the find out whether certain hysological changes affects the vulnerability of liver tissue. To reach this goal, i've developed a method which simulates the impact/compression injuries in a quasi-static way.

Sample removing tool

I used a square-shaped sample tissue removal tool, which was 3,5x3,5 cm in internal size and 2 cm in height, and had a cutting edge.

Measurments

I have used a Mecmesin AFG-500 digital force gauge (0-500 N measurement range, 0.1 N resolution) capable of compression and pulling for the measurments. The force gauge and the sample tray were incorporated into a test stand. The test stand was equipped with a downward facing rod with a square-shaped head with a 1 cm^2 sized flat metal surface. A steadily increased pushing force has been applied on the capsular surface of the liver block. The breakthrough pressure resulting in the rupture of the capsule and lacerating the liver parenchyma was registered as peak pressure (Pmax) and electronically registered by the force gauge. Liver samples from 135 autopsies were analysed.

I evaluated the hystological samples under microscope using haematoxylin-eosin (HE) staining, and six group was formed upon the hystological appearance:

1. group: intact, without steatosis or fibrosis („intact")
2. group: mild steatosis, wich affect less than third of liver cells („mild")
3. group: moderate steatosis, affectng 33-66 % of liver cells („moderate")
4. group: severe steatosis, affectng more than 66 % of liver cells („severe")
5. group fibrosis with or without steatosis ('fibrosis')
6. group: cirrhosis with or without steatosis („cirrhosis")

Statistical analysis

Statistical analysis was performed with SPSS 21 (IBM) statistical suit. Multivariate analysis (Kruskal-Wallis test) was used for comparison of max force between groups. Where statistically significant difference ($p<0.05$) was found, pairwise comparisons were performed to determine differences between relevant groups. In pairwise comparisons significance levels were adjusted for multiple comparisons. Relation between max force and age was tested with linear correlation. R^2 was calculated. Level of significance was 0.05.

Results

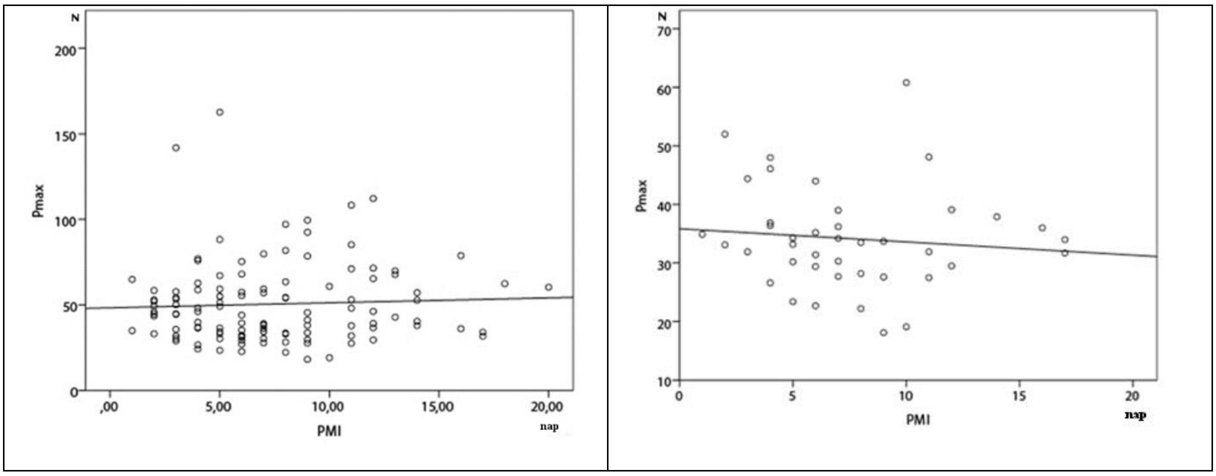
90 samples were from males and 29 were from females, the average age was 58.72 (SD: ±18.79, min-max: 4-100) years. The post-mortem-interval was between 1 and 20 (average: 7.32, SD±4.04) days.

41 liver samples showed no microscopic sign of structural change (group 1), 33 samples showed mild steatosis (group 2), 12 samples showed medium-grade steatosis (group 3), 6 samples showed severe steatosis (group 4), 11 samples showed fibrosis (group 5) and 16 definite cirrhosis (group 6). Most of the fibrotic and cirrhotic samples were also showed some level of fatty infiltration. The registered Pmax values ranged from 18.1 to 162.7 N (average: 50.41 N, SD±23.63).

Group	N	average age (min-max, SD±) (év)	average PMI (min-max, SD±) (nap)	average Pmax (min-max) (N)	Pmax SD (N)
1. Intact	41	57.4 (4-88, 22.98)	7.5 (1-17, 3.98)	34.1 (18.1-60.8)	8.7
2. Mild	33	54.5 (19-89, 17.15)	6.7 (2-20, 3.98)	44.6 (24,2-79,8)	12.6
3. Moderate	12	57.4 (28-70, 11.56)	6.3 (2-18, 4.84)	55.4 (28,9-92,5)	16.0
4. Severe	6	63.3 (55-70, 9.56)	6.5 (1-12, 4.50)	57.6 (39,8–71,5)	11.9
5. Fibrosis	11	65.2 (33-100, 21.3)	7.7 (2-12, 3.43)	65.5 (37,8-112,2)	19.5
6. Cirrhosis	16	65.5 (44-91, 12.89)	8.8 (3-16, 4.03)	87.1 (52.76-162.7)	30.3

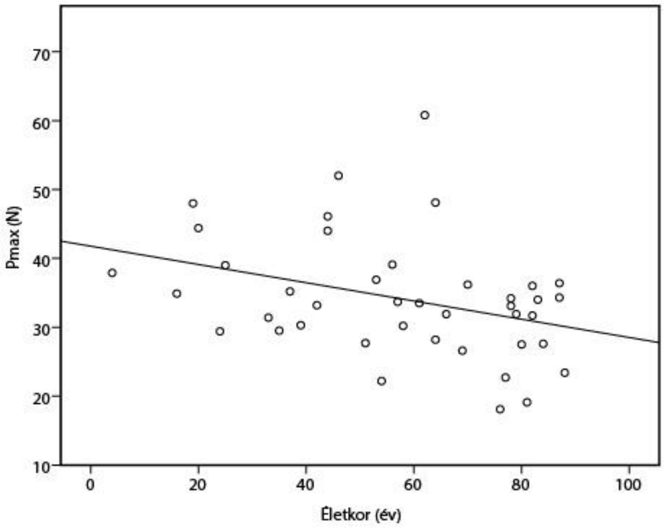
Pmax in different hystological groups

The possible correlation between PMI and PMax was analysed to assess the possible effect of PMI on blunt force vulnerability of liver tissue. No correlation was found between the PMI and the measured Pmax values ($p=0.630$). No correlation was found between the PMI and PMax in the intact liver group ($R2=0.002$ $p=0.592$)



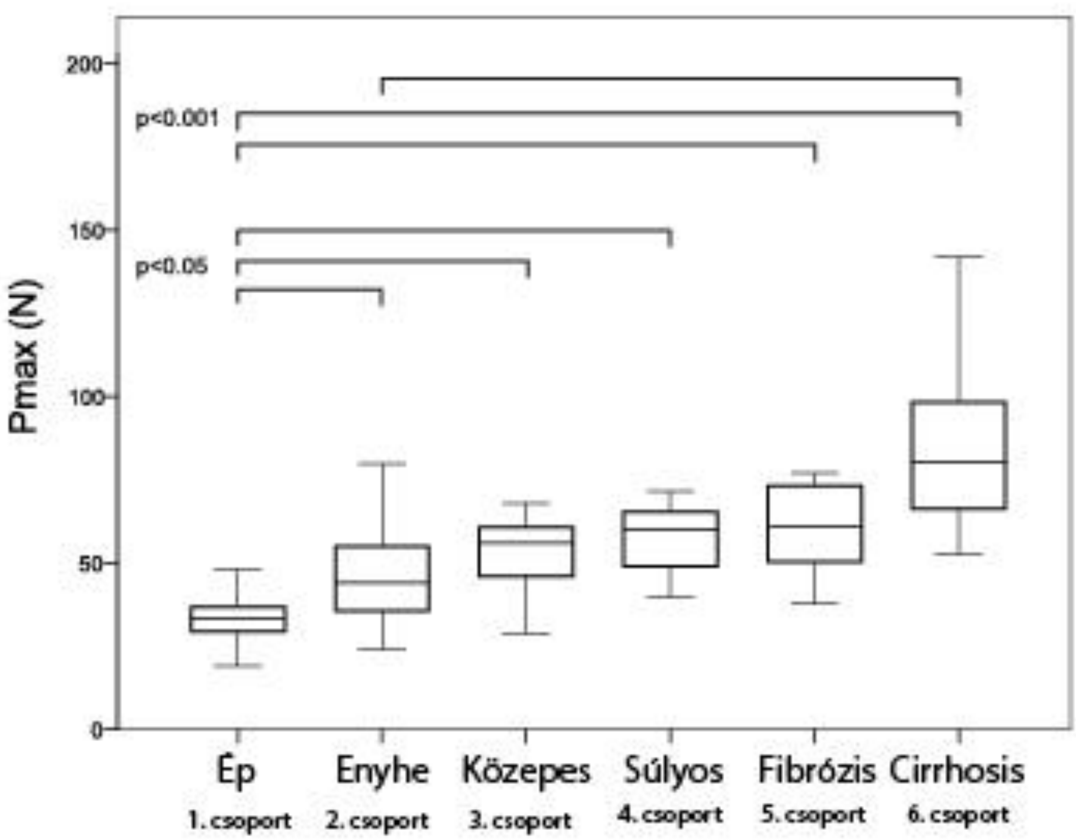
Correlation between PMI and PMax

The effect of age on liver vulnerability was also assessed, and age of the deceased in the intact group showed weak correlation with the Pmax values (R2=0.122, p=0.025).



Correlation between age and PMax

The Pmax values were significantly higher in samples with microscopic structural changes than in intact liver samples (p=0.023, 0.001, 0.009, 0.0001, 0.0001 between group 1 and groups 2 to 6 respectively). Significant difference was found between mild steatosis (group 2) and cirrhosis (group 6) (p=0.0001). The difference between mild, moderate and severe steatosis (group 2-4) was not significant.



Comparisation of PMax values of hystological groups

Multivariate regression analysis of the complete dataset did not reveal previously unidentified correlations with regard to the parameters evaluated. The histological feature based classification strongly correlates with the Pmax ($p<0.001$), while age and PMI have no significant effect on Pmax.

Dynamic compression measurments

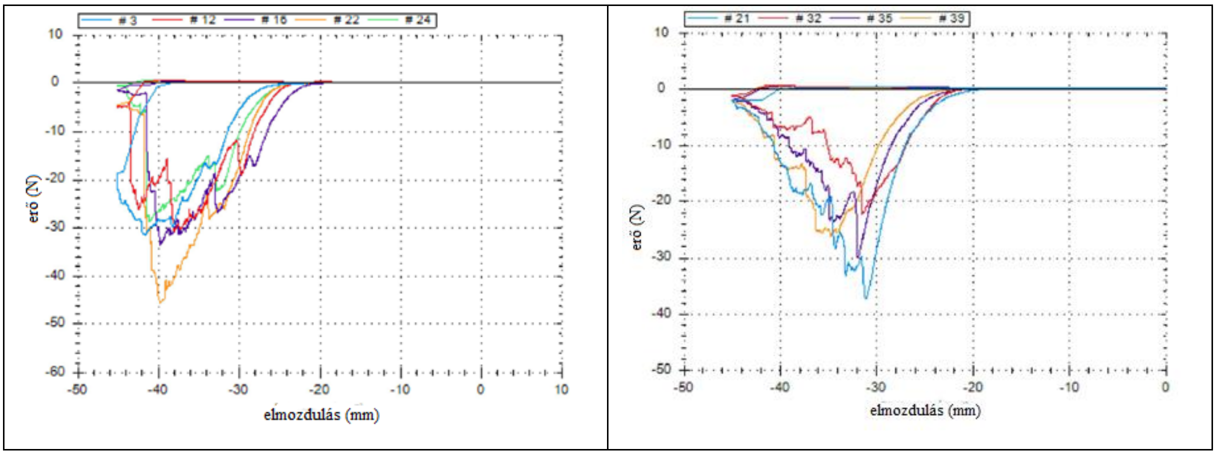
24 samples were analysed, from which 4 samples were excluded because of sings of putrification during the hystological examination.

The dynamic compression measurments were performed with a Mecmesin AFG-500 force gauge fixed to a Mecmesin Multitest-dv 2.5 számítógéppel automatic test stand. The test stand was moving the force gauge downwards with a persistent, pre-defined speed, and the force is registered with a VectorPro Lite Software. The AFG-500 also registered the maximum force.

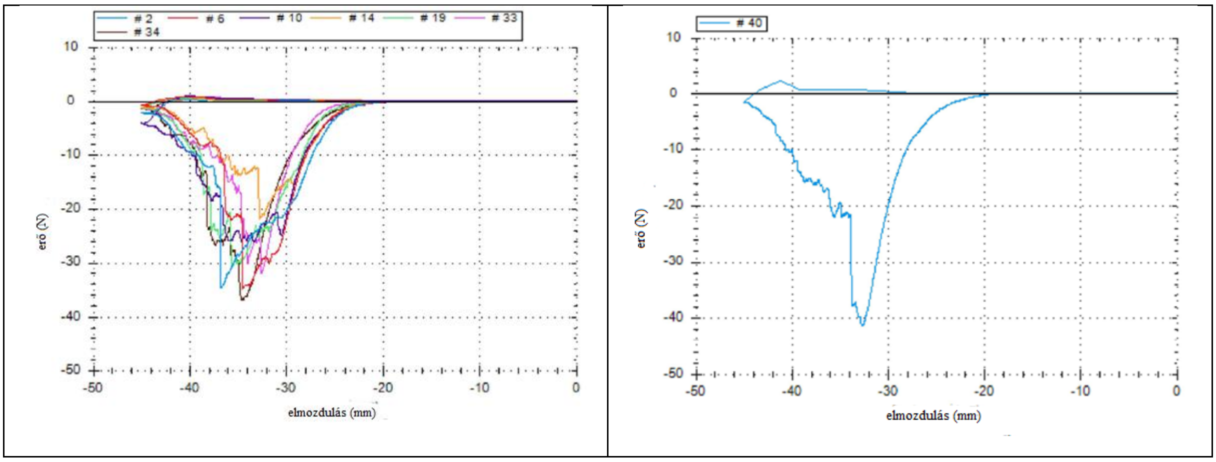
The compression was transferred to the tissue with a metal rod 8 mm in diameter (Mecmesin Radiused Probe - 500 N, 10-32 UNF, 8 mm external diameter) to the liver tissue. During the hystological examination, 9 sample was intact (1.), 7 showed mild steatosis (2.), 1 showed moderate steatosis (3.), and 3 cirrhosis (6.).

No	F_{max} (N)	σ_{max} (N/mm^2)	F_r (N)	σ_{sz} (N/mm^2)	σ_{sz}/σ_{max}	E_{linmax} (N/mm^2)	Age (year)	M/F	PMI (day)
3	**31,6**	**0,63**	**16,2**	**0,32**	**0,51**	**0,473**	**21**	**M**	**3**
12	**30,8**	**0,61**	**19,1**	**0,38**	**0,62**	**0,866**	**9**	**M**	**1**
16	**33,7**	**0,67**	**16,9**	**0,34**	**0,51**	**0,785**	**22**	**F**	**4**
21	**37,3**	**0,74**	**37,3**	**0,74**	**1**	**1,228**	**34**	**M**	**9**
22	**37,4**	**0,74**	**26,0**	**0,52**	**0,70**	**0,866**	**20**	**M**	**3**
24	**28,8**	**0,57**	**21,2**	**0,42**	**0,73**	**0,748**	**65**	**M**	**3**
32	**22,4**	**0,45**	**22,4**	**0,45**	**1**	**0,713**	**52**	**M**	**10**
35	**30,1**	**0,60**	**30,0**	**0,60**	**1**	**0,972**	**67**	**M**	**3**
39	**26,4**	**0,52**	**21,5**	**0,43**	**0,82**	**0,747**	**64**	**M**	**4**
$Average_{in}$	*30,9*	*0,61*	*23,4*	*0,46*	*0,76*	*0.822*	*39.3*		*4.4*
Min-Max	*22,4-37,4*	*0,45-0,74*	*16,2-37,3*	*0,32-0,74*	*0,51-1*	*0,47-1,2*	*9-67*		*1-10*
SD±	*4,86*	*0,09*	*6,75*	*0,13*	*0,20*	*0,20*	*22,78*		*3,00*
2	**34,8**	**0,69**	**18,5**	**0,37**	**0,53**	**0,712**	**60**	**M**	**2**
6	**35,0**	**0,70**	**27,4**	**0,55**	**0,78**	**0,895**	**33**	**M**	**3**
10	**26,2**	**0,52**	**24,8**	**0,49**	**0,94**	**0,837**	**67**	**M**	**12**
14	**21,9**	**0,43**	**25,2**	**0,30**	**0,70**	**0,602**	**62**	**M**	**5**
19	**30,6**	**0,61**	**24,4**	**0,49**	**0,80**	**0,778**	**25**	**M**	**2**
33	**31,9**	**0,63**	**31,6**	**0,63**	**1**	**1,008**	**58**	**M**	**4**
34	**37,0**	**0,73**	**36,1**	**0,72**	**1**	**0,975**	**59**	**M**	**3**
$Average_{mi}$	*31,0*	*0,61*	*26,8*	*0,50*	*0,82*	*0,83*	*52*		*4,42*
Min-Max	*21,9-37*	*0,43-0,73*	*18,5-36,1*	*0,3-0,72*	*0,53-1*	*0,62-1,01*	*25-67*		*2-12*
SD±	*5,37*	*0,10*	*5,64*	*0,14*	*0,17*	*0,14*	*16,1*		*3,50*
40	**41,5**	**0,83**	**41,5**	**0,83**	**1**	**1,246**	**57**	**M**	**4**
18	**47,1**	**0,94**	**44,6**	**0,89**	**0,94**	**1,526**	**41**	**F**	**8**
25	**53,3**	**1,06**	**52,9**	**1,04**	**0,98**	**1,803**	**67**	**F**	**11**
28	**76,6**	**1,52**	**76**	**1,51**	**1**	**2,348**	**68**	**F**	**12**
$Average_{cir}$	59	1,17	57,8	1,14	0,97	1,89	58,6		10,3
Min-Max	47,1-76,6	0,94-1,52	44,6-76	0,89-1,51	0,94-1	1,53-2,35	41-68		8-12
SD±	15,5	0,30	16,3	0,32	0,03	0,41	15,3		2,08

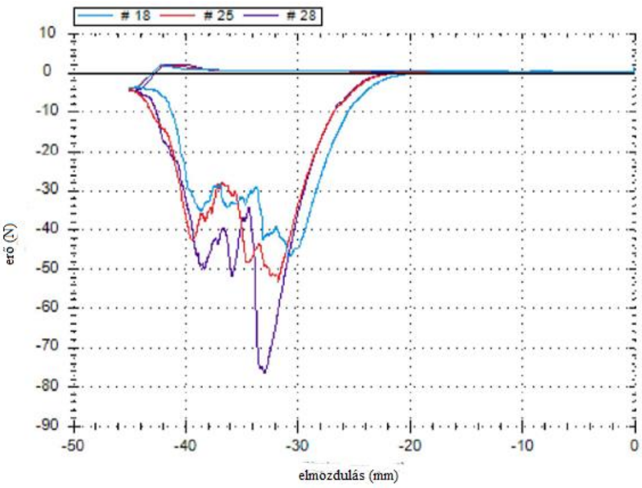
Previous table: Results of dynamic measurments in intact samples, mild steatosis, moderate steatosis, and cirrhosis. Legend: No: ID number of sample, F_{max}: maximal force; $\sigma_{max:}$ maximal strain; F_r: Force at first rupture; σ_{sz}: strain at first rupture; E_{linmax}: Young modulus)



Measurements curves from intact samples



Measurements curves from samples with mild and moderate steatosis



Measurements curves from samples with cirrhosis.

Correlation between the measured/calculated data and the hystology was analyzed with ANOVA. $\mathbf{F_{max}}$, a $\mathbf{F_r}$, $\boldsymbol{\sigma_{max}}$, $\boldsymbol{\sigma_{sz}}$ and $\mathbf{E_{linmx}}$ values were significantly larger in samples with cirrhosis (6.) than in case of intact samples (1.) and samples with mild steatosis (2.). No significant difference was found between intact samples and samples with mild steatosis.

Summary of results

Results from autopsy data and measurements during autopsy can be summarized as follows:

- Liver weight shows correlation with body height, but correlation is stronger if hystology is also considered.
- Average liver weight decreases with age, but histological changes (fibrosis) play a pivotal role, because there was no correlation between age and liver weight in samples without histological changes.
- Steatosis heptatis is accompanied by the increase of liver weight, but fibrosis and cirrhosis – without steatosis – does not increase liver weight.
- There is good correlation between liver weight and liver dimensions.
- Steatosis hepatis affects mostly the sagittal (AP) diamater, but soes not affects the witdh.
- Thickness of fat tissue correlates well with liver size, but not with hystology.
- There is no correlation between liver weight and injury risk.
- Steatosis does not affects injury risk, but fibrosis and steatosis decreases.
- There is significant correlation between the size of the force and injury rate.
- There is no correlation between the thickness of thoracical/bdominal fat tissue and injury rate.

Results of in vitro biomechanical measurments of liver samples with different pathological state can be summarized as follows:

- In quasi-static measurements, significantly larger force was needed to create a rupture in samples with steatosis, fibrosis, and cirrhosis, than in intact samples. Significantly larger force was needed to create a rupture in samples with cirrhosis, than in samples with mild steatosis.
- The age increased the vulnerability slightly in intact samples, but no such correlation was found if results of all samples are compared.

- In dynamic compression measuremets, the maxmal force, force needed for rupture, maximal stress, strass at rupture was significantly larger in cirrhotic samples than in intact samples or samples with mild steatosis.
- Elastic modulus was significantly larger in cirrhotic samples than in intact samples or samples with mild steatosis. No such correlation can be found between intact samples and samples with mild steatosis.

Discussion

The different pathological structural changes are also necessarily altering the biomechanical properties of tissues due to the shifts in tissue element proportions. The knowledge about the effect of these changes on biomechanical properties can largely ease and put to a scientific base the assesment of that questions, whether certain structural changes played any role in the developement of certain injuries. It makes a valid – based not only on previous experiences or statistical datas – assessment, whether the affected organ is more vulnerable or not.

Out of factors playing a role in organ injuries, hystological changes are affecting liver weight and dimensions. Steatosis hepatis increases liver weight. If there is no steatosis present, than the fibrosis alone does not increase liver weight (so this factor does not plays a role in injuries in this regard). Liver dimensions increase usually with the increase of weight proportionally, but steatosis increasis primarly the sagittal diameter.

Based on the measurement results, it could be stated, that steatosis does not increase liver vulnerability, moreover in contrast with some data from the scientific literature – depending on its severity – decreases it. This effect can be proved by quasi-static measuremets results, but not with dynamic test sin case of mild steatosis. This has to be examined with larger sample number and with other factors (e.g. thickness of capsule) taken into account. The single sample in dynamic tests with moderate steatosis already showed decreased vulnerability compared with intact samples.

The increased liver weight in case of steatosis will cause larger mechanical stress in tissues during acceleration and decelaration injury mechanisms, but no increased vulnerability should be considered even in these cases. The measeurment results agree with the statistical data from autopsies. Rate of liver injuries does not increase with larger liver size or steatosis.

It can be seen by both quasi-static and dynamic measurement results, that fibrosis and cirrhosis significantly decrease the vulnerability of liver tissue, and – if no steatosis is present – thay does not increase liver weight. It can be stated from these results, that liver vulnerability decreases if fibrosis or cirrhosis is present, and so injury occures in a smaller probability if the size of the force is the same. The measurment results agree with the statistical data from autopsies. Rate of liver injuries decrease in case of fibrosis or cirrhosis are present.

Measurement results show, that liver vulnerability slightly increases with age, but this is compensated with the pathological changes becoming more frequent as age increases. So histological alterations are more important than age.

The increased collagen, and fat content explains the increased strength of the tissues. The dynamic tests show, that increased collagen content decrease tissue deformation to the same forces.

The appreciably different measurement results in samples with similar hsytological picture can be explained by various factors. Collagen contant can differ significantly in absolute quantity and type even in similar hystological appearance, and liver vulnerability is greatly affected by the strength of capsule, which is basically defined by its thickness and collagen content. The importanc of the latter is supported by the dichotomy in dynamic tests (one or two-step rupture). The orientation of collagen fibers also affects the biomechanical properitis of tissues, so this factor also plays a role in resistance of parenchyma and capsule against forces. The experiments in this thesis does not streched to the examination of this factors, since my primary goal was to reach conclusions helping everday forensic practive based on objective datas which are gained from routine examinations – which is haematoxiline-eosin staining by the governmental decree of 351/2013.

The results contradicts the statments based on theretical considerations (and not supported by references) found in some textbooks that steatotic, fibrotic or cirrhotic liver would be more vulnerable. The experiments methodize the partial recognitions of previous scientific literature into coherent whole. Statistical analysis of autopsy results supported the experimntal findigs, validating the experimental findings with practice.

If the question about the role of structural liver changes emerges during forensic practice, than it can be stated based on present results, that those does not increased the risk of injury. In cases of cirrhosis the liver injury risk is lower.

Results can be also usefull for vehicle safety engineering, because they prove, that stressing for healthy persons is sufficient, extending the modelling of the human body to pathological changes is not necessary.

The objective measrement method is suited for the examination of different organs – like lung, spleen or kidney, and the examination of our hypotheseses can be extended also to injuries cauesd by different methods like cuts or stabs.

Summary of new results

1/a. Larger body height attends larger liver weight.

1/b. Age alone does not affect liver weight.

1/c. With the increase of liver weights, its dimensions are proportionally increase.

1/d. Steatosis increases liver weight but fibrosis don’t.

1/e. Steatosis increases mostly the antero-psoterior dimaeter, and does not increase the horizontal.

2/a. Prevalence of liver injury increases with the size of the force.

2/b. Prevalence of liver injuryis not affected by steatosis.

2/c. Prevalence of liver injury is decreased by fibrosis or cirrhosis.

2/d. Increase weight does not affect the prevalence of liver injuries.

2/e. Prevalence of liver injury is not affected by thoracic or abdominal fat tissue

3. The compression measurments with force gauge is appropriate for the objective examination of liver tissue vulnerability.

4/a. Mild steatosis does not increase vulnerability of liver tissue to blunt force injuries, and severe steatosis decreases it.

4/b. Fibrosis (and so cirrhosis) decreases liver vulnerability.

The thesis based on the following scientific publications

Gábor Simon, Viktor Soma Poór, Veronika Heckmann, Zsolt Kozma, Tamás F. Molnár. *The effect of steatosis and fibrosis on blunt force vulnerability of the liver.* Int J Legal Med. 2020; 134(3): 1067–1072. doi: 10.1007/s00414-019-02245-4 **IF: 2.222 (2019), Journal Ranking: Q1**

Gábor Simon, Veronika Heckmann, Dénes Tóth, Dénes Pauka, Karola Petrus, Tamás F. Molnár. *The effect of hepatic steatosis and fibrosis on liver weight and dimensions*. Leg. Med. Accepted: 2020.08.23. **IF: 1.195 (2019), Journal Ranking: Q2,** Gábor Simon, Veronika Heckmann, Dénes Tóth, Zsolt Kozma**.** *Brain death of an infant caused by a penetrating air gun injury.* 2019 Jul;39:41-44. doi: 10.1016/j.legalmed.2019.06.004 **IF: 1.195, Journal Ranking: Q2, Independent citation: 1**

Other scientific publication

Dr. Simon Gábor, Dr. Rácz Evelin, Dr. Mayer Mátyás, Dr. Heckmann Veronika, Dr. Tóth Dénes, Dr. Kozma Zsolt (2017) *Suicide by Intentional Air-embolism.* J Forensic Sci. 2017 May;62(3):800-803. doi: 10.1111/1556-4029.13320 **IF: 1.184, Journal Ranking: Q2, Indeprndent citation: 4**