Using an Excel Spreadsheet for T2* Calculations:

The DOs and DON'Ts

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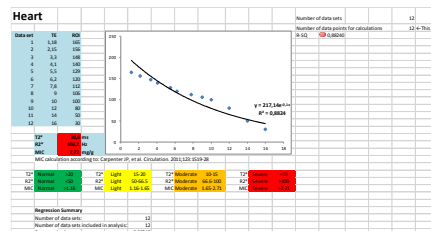Jose Michel Kalaf Research Institute

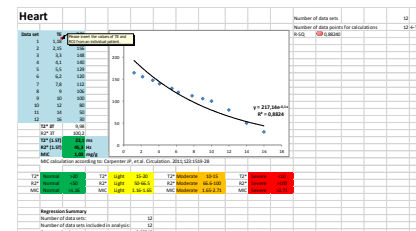Campinas, Brazil

What you need

1. A spreadsheet program that supports an MS-Excel file

2. The spreadsheet model (link below – click to open)

3. A workstation or software to draw regions of interest (ROI)s in the original MRI images

(this is standard in any MRI scanner – can be done by the technician in the scanner)
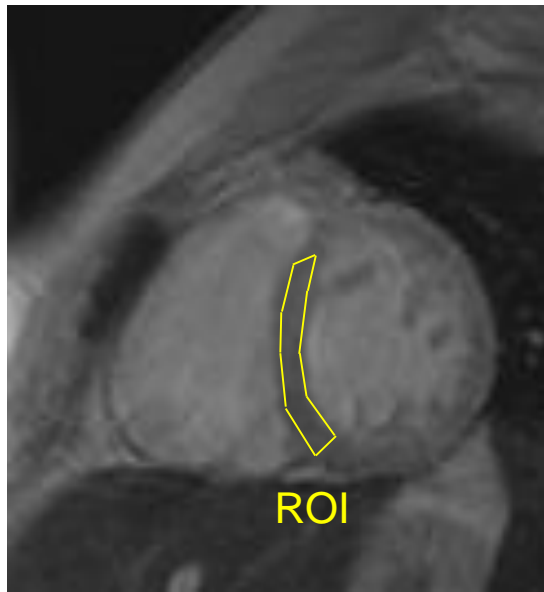

1.5T

3.0T

Step 1

1. Acquire the images in your scanner and import them into the workstation/DICOM

   software for ROI drawing

Heart
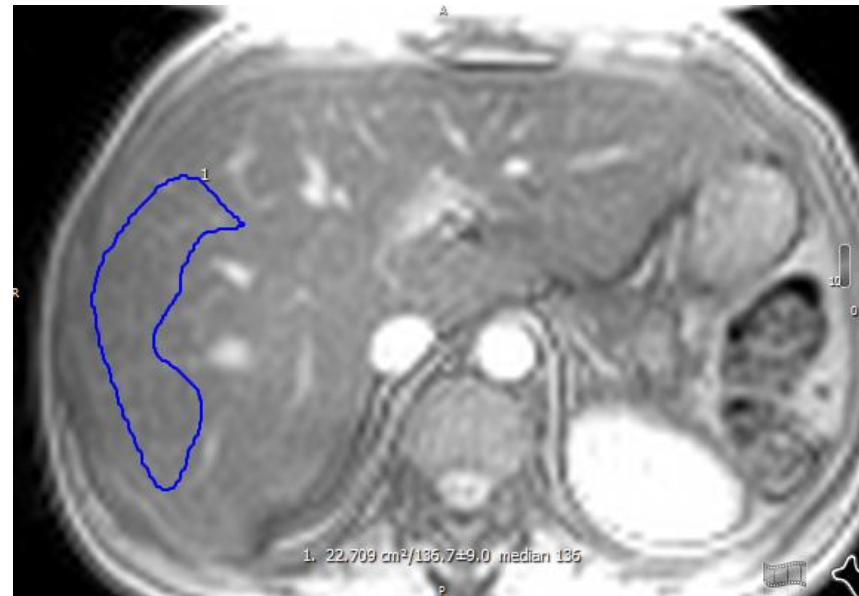
Liver

Step 1 - pitfalls

Include the subendocardium and subepicardium layers but avoid blood signal from ventricles. Include only the septum avoiding artifacts. Adjust for respiration and copy same ROI across all images.

Avoid major vessels. No need to cover whole liver, but sufficient for large part of the right lobe as shown. Copy the same ROI across all images.

Step 2 – getting the numbers from the images (TE and SI)

Each image will generate a pair of numbers: the TE and the mean signal intensity (SI) of the drawn ROIs
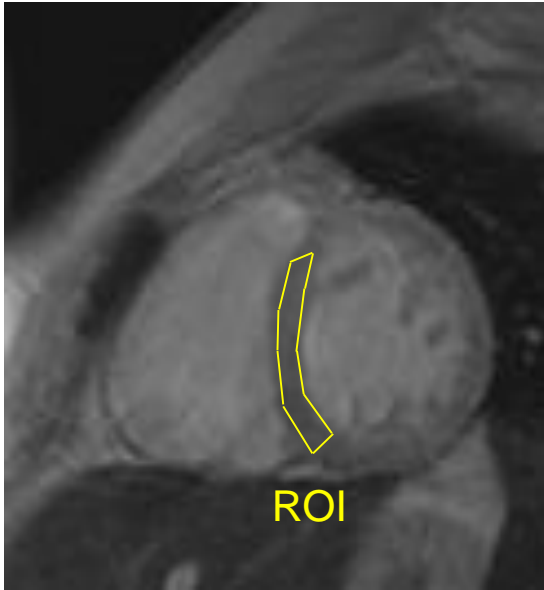
Write down these numbers to transfer them to the spreadsheet

TIP: the TEs will be the same for every exam – so you will only have to identify the SI and keep the same TEs for every patient after doing it for the first time.
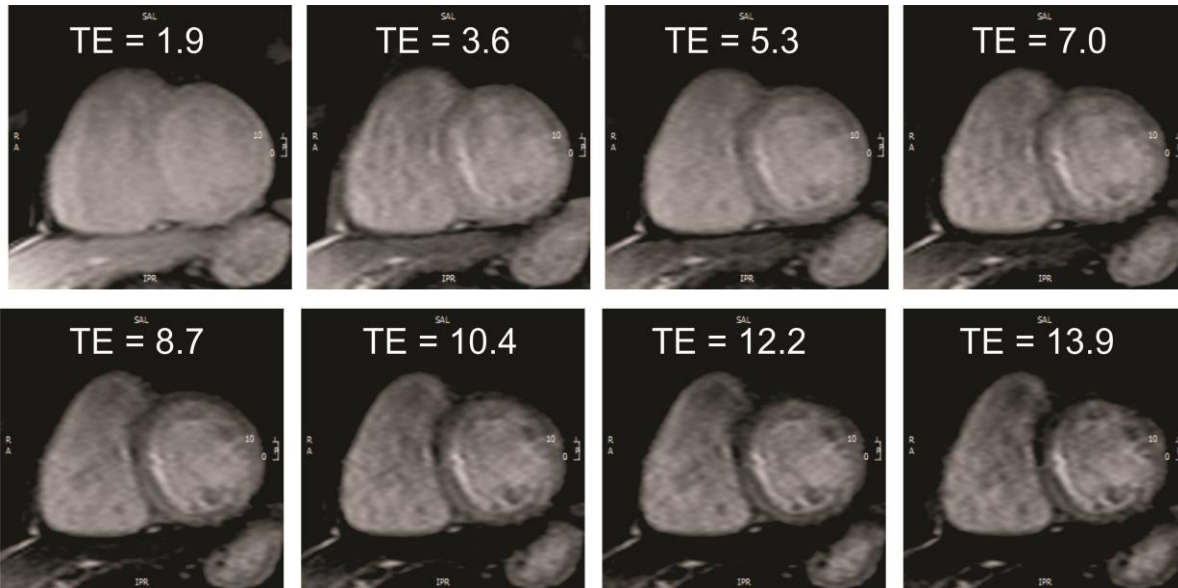
frame	TE (ms)	mean SI
0	1.9	89.5
1	3.6	83.6
2	5.3	76.8
3	7.0	70.6
4	8.7	64.5
5	10.4	59.2
6	12.2	54.9
7	13.9	50.2
8	15.6	45.8
9	17.3	42.4

Step 3 – open the spreadsheet

The spreadsheet will have tabs on the bottom: use the heart and liver tabs for each organ respectively
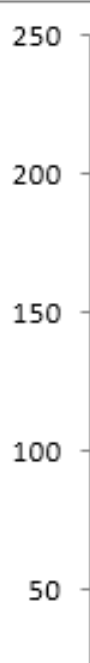
TIP: there is one spreadsheet for 1.5T and another for 3.0T – use the one appropriate to your scanner
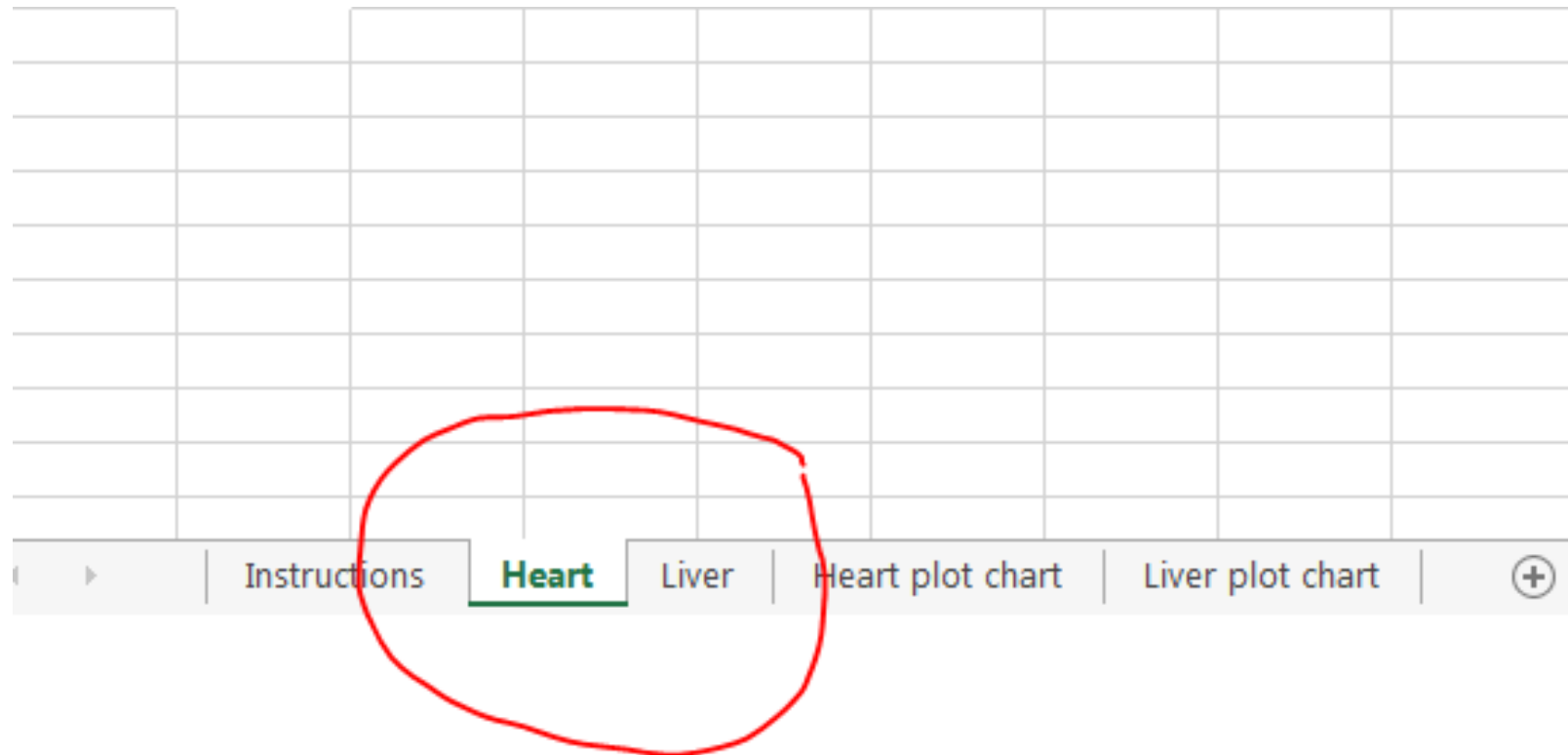
Step 4 – Insert the values for the heart

Insert the TEs and ROI values in the two columns identified in blue in the left of the spreadsheet in the heart tab.

Heart

Data set	TE	ROI
1	1,18	165
2	2,15	156
3	3,3	148
4	4,1	140
5	5,5	129
6	6,2	120
7	7,8	112
8	9	106
9	10	100
10	12	80
11	14	50
12	16	30

250
200
150
100
50

As you type in the numbers, you will notice that the graph and some values will change automatically as you type.

TIP: You can include up to 12 datasets. You will be able to delete them or use fewer number later.

Step 5 – Observe the results reported

Heart

Data set	TE	ROI
1	1,8	185
2	3,6	176
3	5,5	159
4	7,2	150
5	8,9	136
6	10,6	127
7	12,3	116
8	14,1	109
9		
10		
11		
12		

Number of data sets   8
Number of data points for calculations   8

◯ 0,99625

$y = 203{,}74e^{-0{,}045x}$
$R^2 = 0{,}9963$

4. The coefficient for the fitting is highlighted (0.99625 e.g.)

1. The points will be updated and the fitting line drawn automatically

T2*	22,4	ms
R2*	44,7	Hz
MIC	1,02	mg/g

2. The T2*, R2* and MIC will be calculated automatically

MIC calculation according to: Carpenter JP, et al. Circulation. 2011;123:1519-28

T2*	Normal	>20		T2*	Light	15-20		T2*	Moderate	10-15		T2*	Severe	<10
R2*	Normal	<50		R2*	Light	50-66.5		R2*	Moderate	66.6-100		R2*	Severe	>100
MIC	Normal	<1.16		MIC	Light	1.16-1.65		MIC	Moderate	1.65-2.71		MIC	Severe	>2.71

3. The normal ranges are given as reference

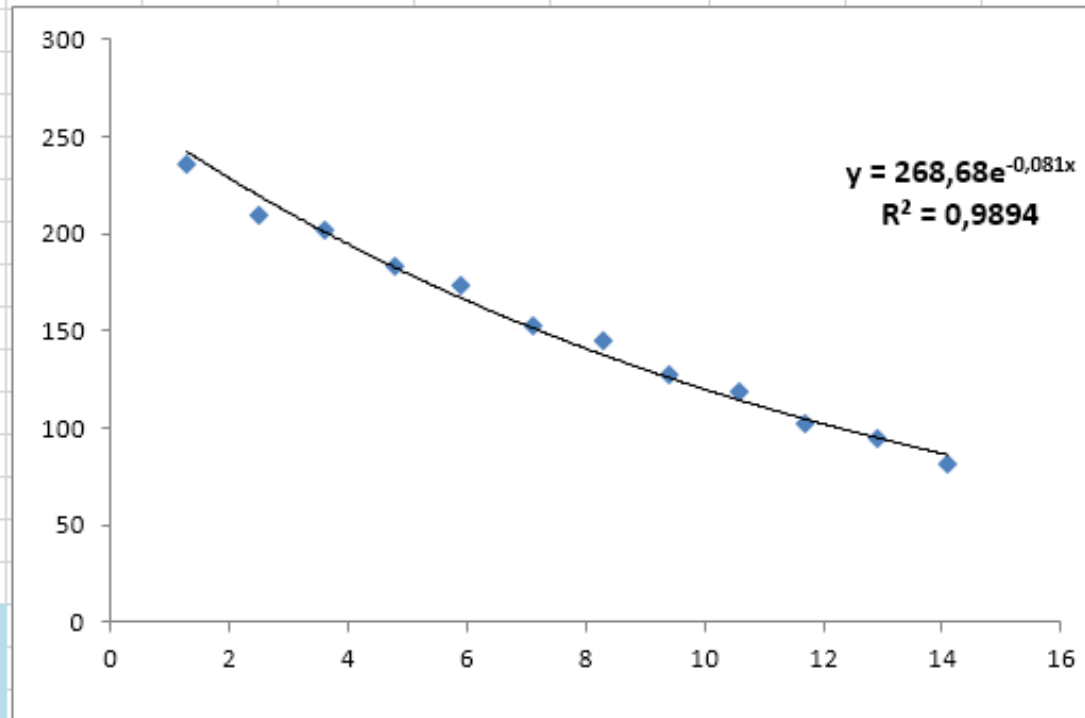# Step 6 – Do the same for the liver (liver tab)

LIVER

Please insert the values of TE and ROI from an individual patient.

Data set	TE	ROI
1	1,3	236
2	2,5	209
3	3,6	202
4	4,8	183
5	5,9	173
6	7,1	153
7	8,3	145
8	9,4	127
9	10,6	119
10	11,7	102
11	12,9	95
12	14,1	81

T2*	12,4	ms
R2*	80,7	Hz
LIC	1,81	mg/g

LIC calculation according to: Hankins JS, et al. Blood. 2009;113:4853-5.

Number of data sets — 12

Number of data points for calculations — 12

R-SQ — ● 0,98942

$y = 268{,}68e^{-0{,}081x}$

$R^2 = 0{,}9894$

T2*	Normal	>11.4		T2*	Light	3.8 - 11.4		T2*	Moderate	1.8-3.8		T2*	Severe	<1.8
R2*	Normal	<88		R2*	Light	88-263		R2*	Moderate	263-555		R2*	Severe	>555
LIC	Normal	<2		LIC	Light	2-7		LIC	Moderate	7-15		LIC	Severe	>15

What to look for

Make sure your correlation coefficients are > 0.98 most of the times.

This assures that the fitting if very good and results should be reliable.

$y = 268,68e^{-0,081x}$
$R^2 = 0,9894$
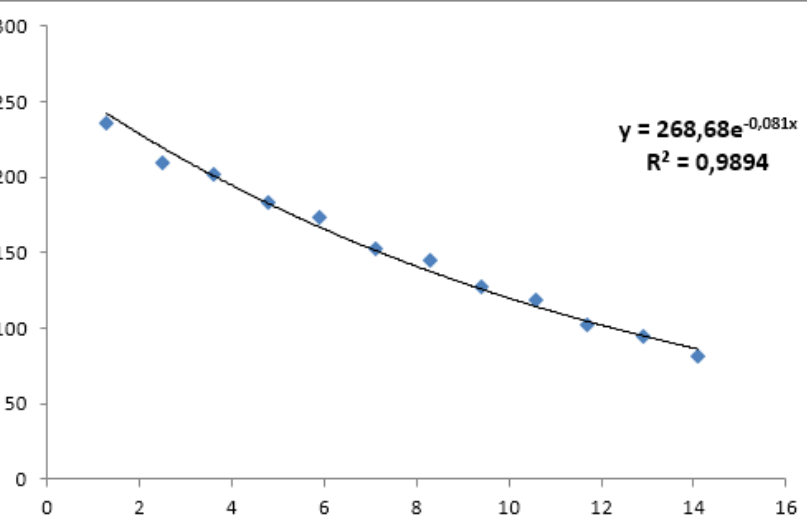
An example of a very good fit
(0.9894)

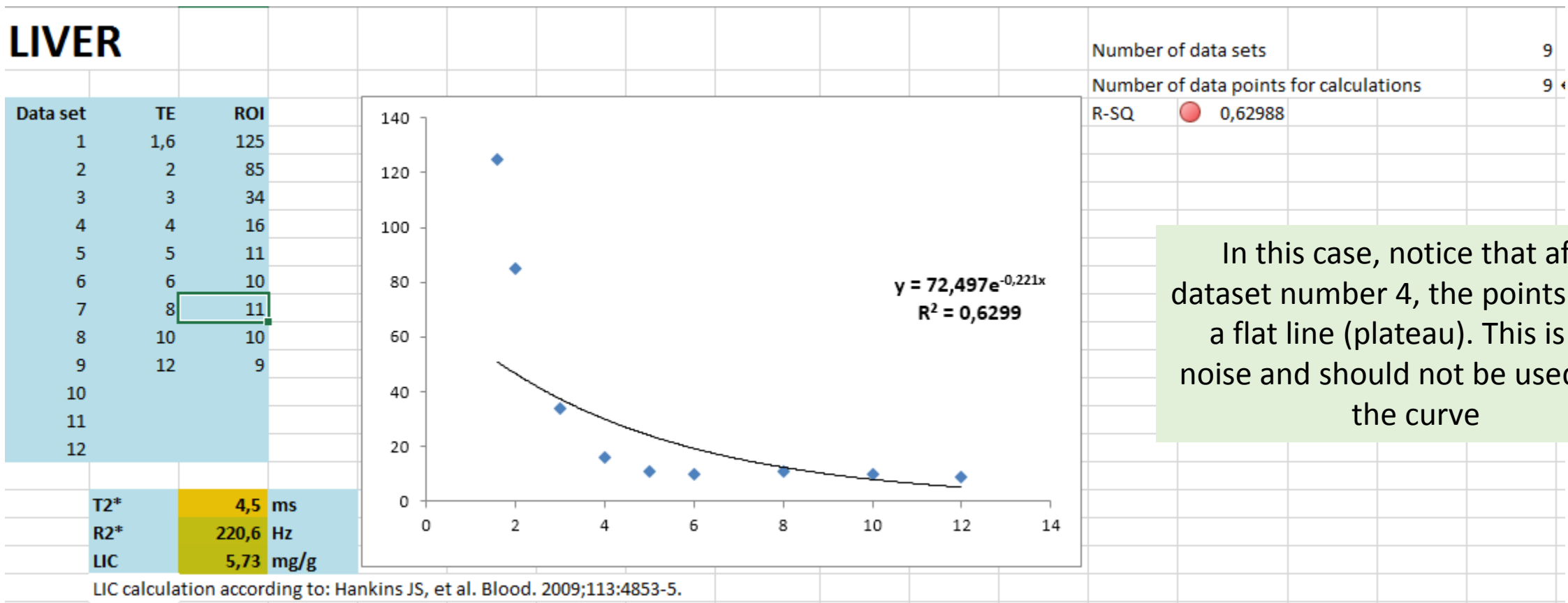| Number of data points for calculations			
R-SQ	●	0,62988	

$y = 72,497e^{-0,221x}$
$R^2 = 0,6299$
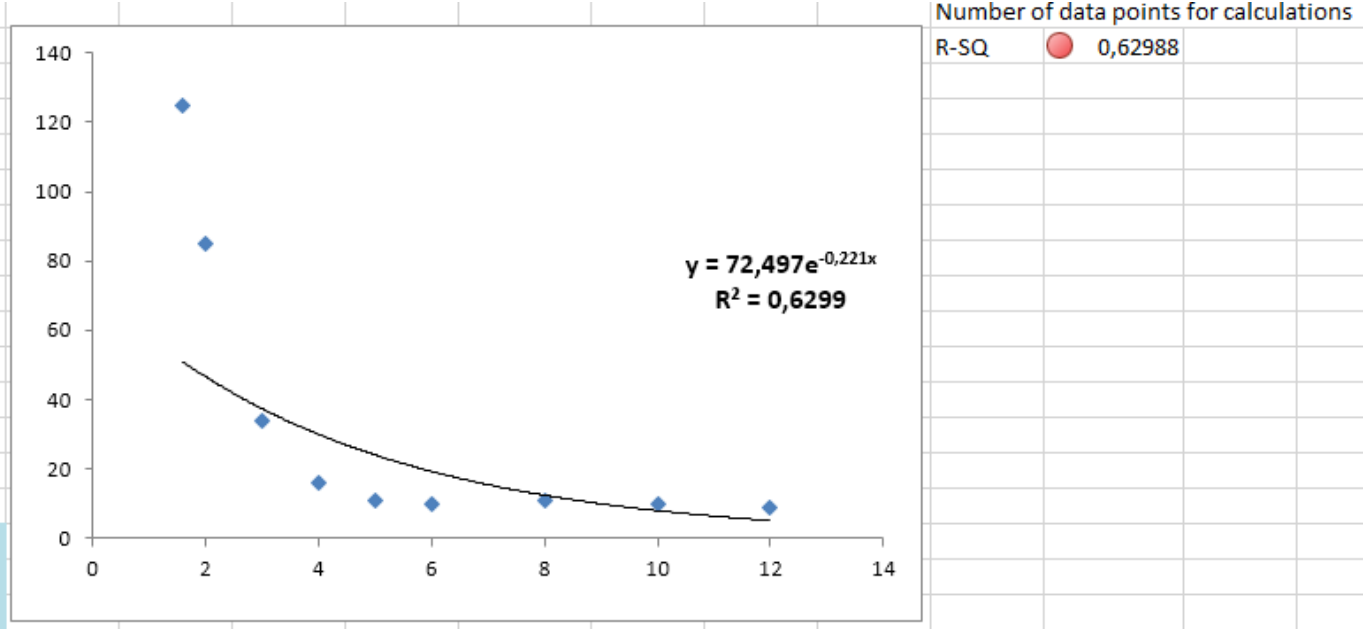
A poor fit (0.6299)

TIP: observe the red circle indicating a poor fit on the right

Solving a bad fit

If you correlation coefficients are > 0.98, do not do anything and accept the values generated.

If not, most of the times the problem is related to how many points were used to fit the curve

LIVER

Number of data sets	9
Number of data points for calculations	9
R-SQ ⬤	0,62988

Data set	TE	ROI
1	1,6	125
2	2	85
3	3	34
4	4	16
5	5	11
6	6	10
7	8	11
8	10	10
9	12	9
10		
11		
12		

$y = 72{,}497e^{-0{,}221x}$
$R^2 = 0{,}6299$

T2*	4,5	ms
R2*	220,6	Hz
LIC	5,73	mg/g

LIC calculation according to: Hankins JS, et al. Blood. 2009;113:4853-5.

In this case, notice that after dataset number 4, the points are on a flat line (plateau). This is just noise and should not be used to fit the curve

TIP: this will underestimate the true LIC/MIC

Truncating

To correct for that, truncate (eliminate) the points that form that flat line. In this case, eliminate datasets 5, 6, 7, 8 and 9:
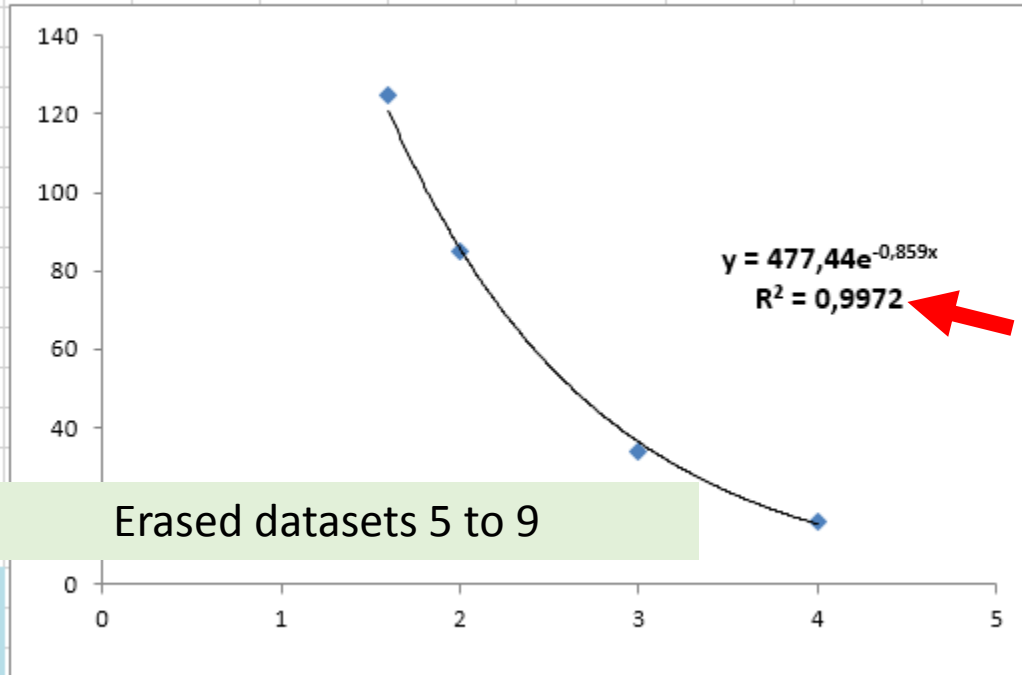

Data set	TE	ROI
1	1,6	125
2	2	85
3	3	34
4	4	16
5	5	11
6	6	10
7	8	11
8	10	10
9	12	9
10		
11		
12		

T2*	1,2	ms
R2*	858,9	Hz
LIC	23,61	mg/g

LIC calculation according to: Hankins JS, et al. Blood. 2009;113:4853-5.

Number of data sets	9
Number of data points for calculations	4
R-SQ	0,99724

$y = 477{,}44e^{-0,859x}$
$R^2 = 0{,}9972$

You can do this just by changing the number of data points used from the original 9 to 4.
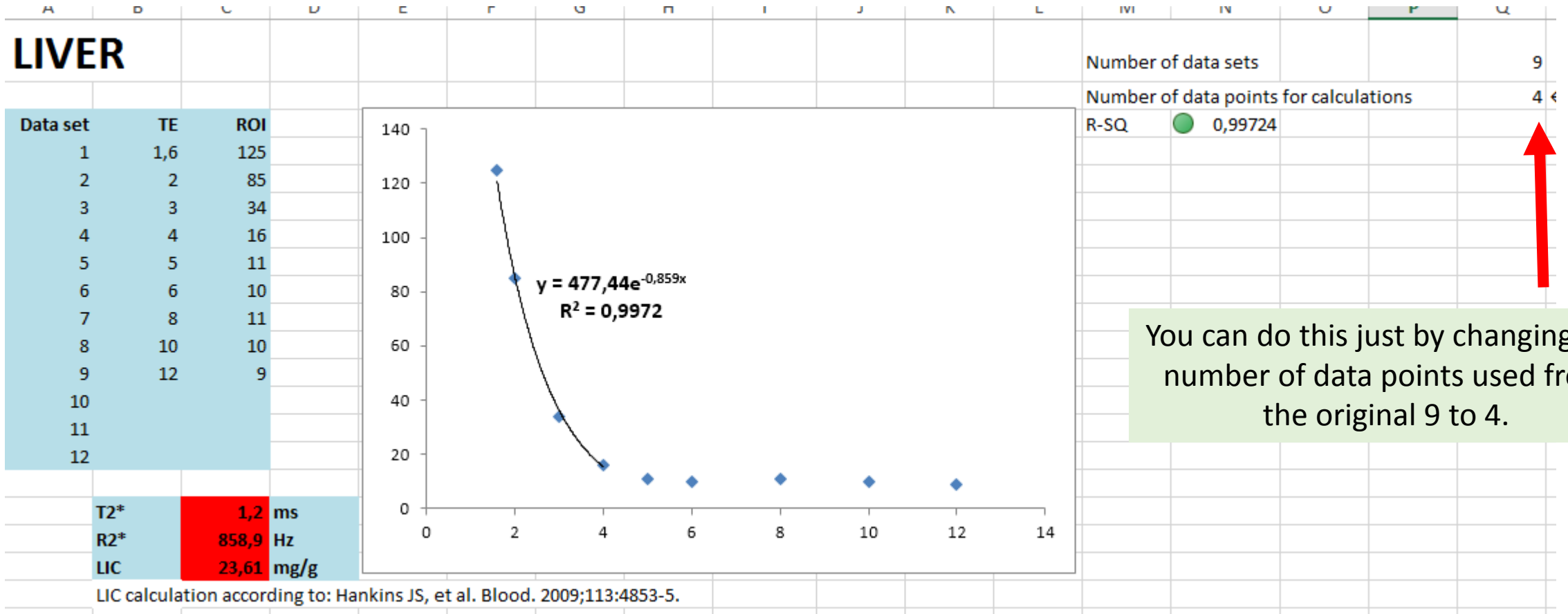
Truncating

Or you can also do this by deleting the number on the left

LIVER

Data set	TE	ROI
1	1,6	125
2	2	85
3	3	34
4	4	16
5		
6		
7		
8		
9		
10		
11		
12		

T2*	1,2	ms
R2*	858,9	Hz
LIC	23,61	mg/g

LIC calculation according to: Hankins JS, et al. Blood. 2009;113:4853-5.

Number of data sets	9
Number of data points for calculations	9
R-SQ	#NUM!

$y = 477,44e^{-0,859x}$

$R^2 = 0,9972$

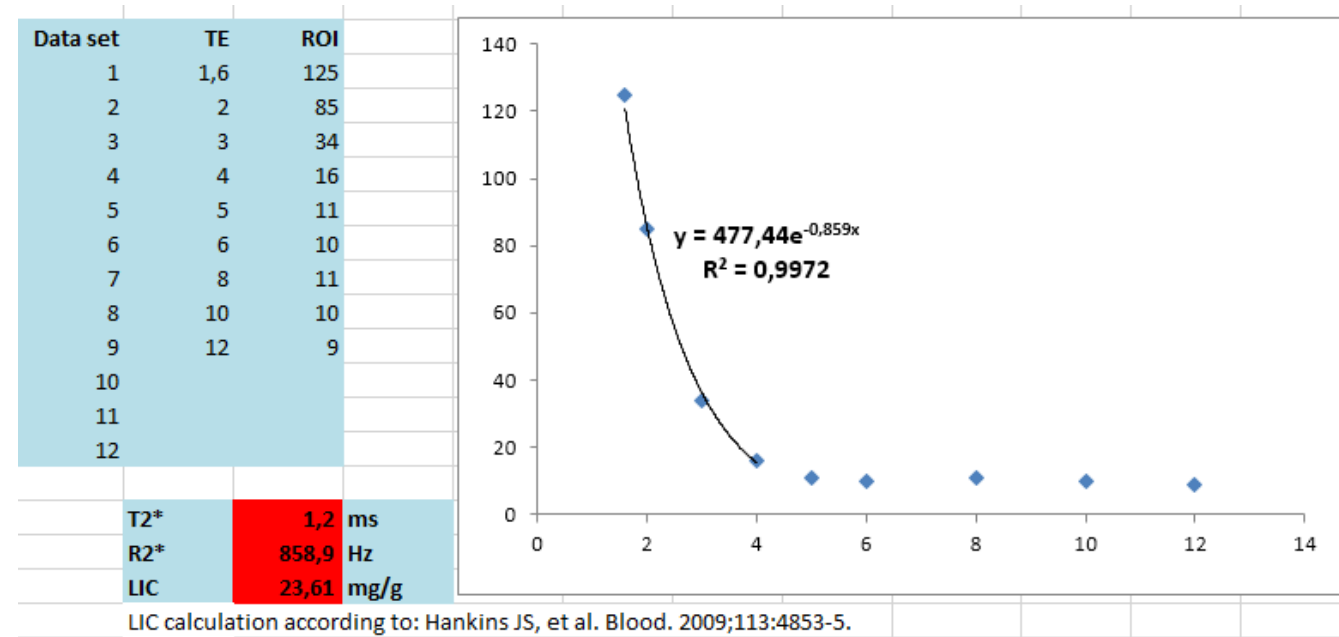R^2 is now 0,9972

Erased datasets 5 to 9

TIP: notice how the true LIC in this case is much higher than the previous one

When to stop truncating

It is a visual analysis most of the times, but a rule of thumb is to do it until you have reached the $R^2 > 0.98$ number
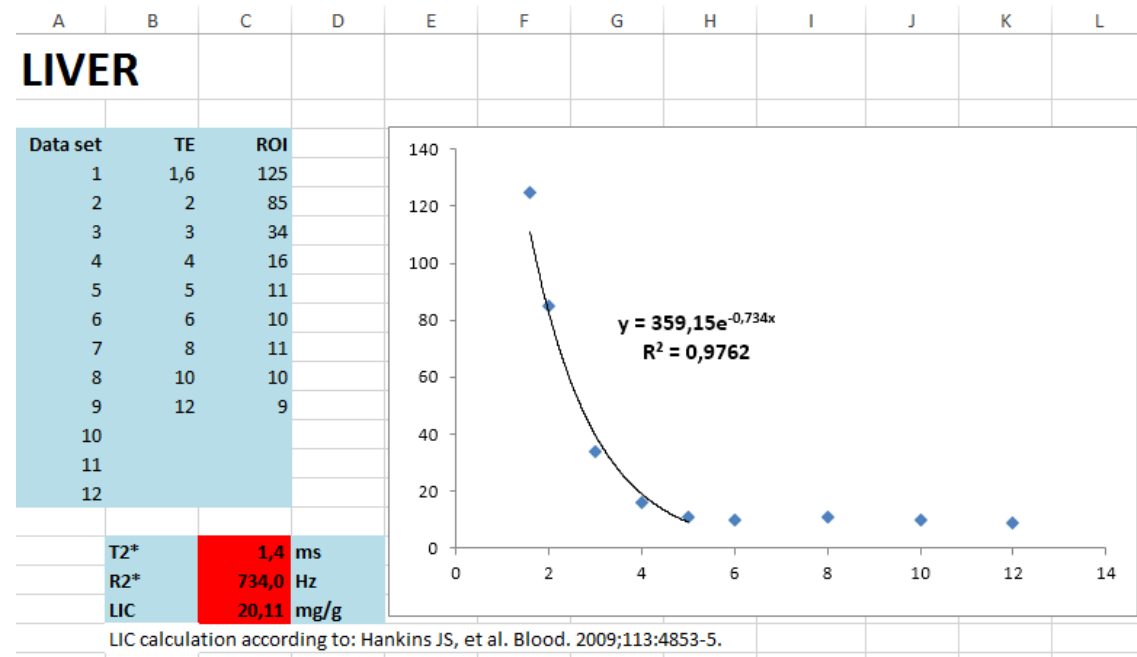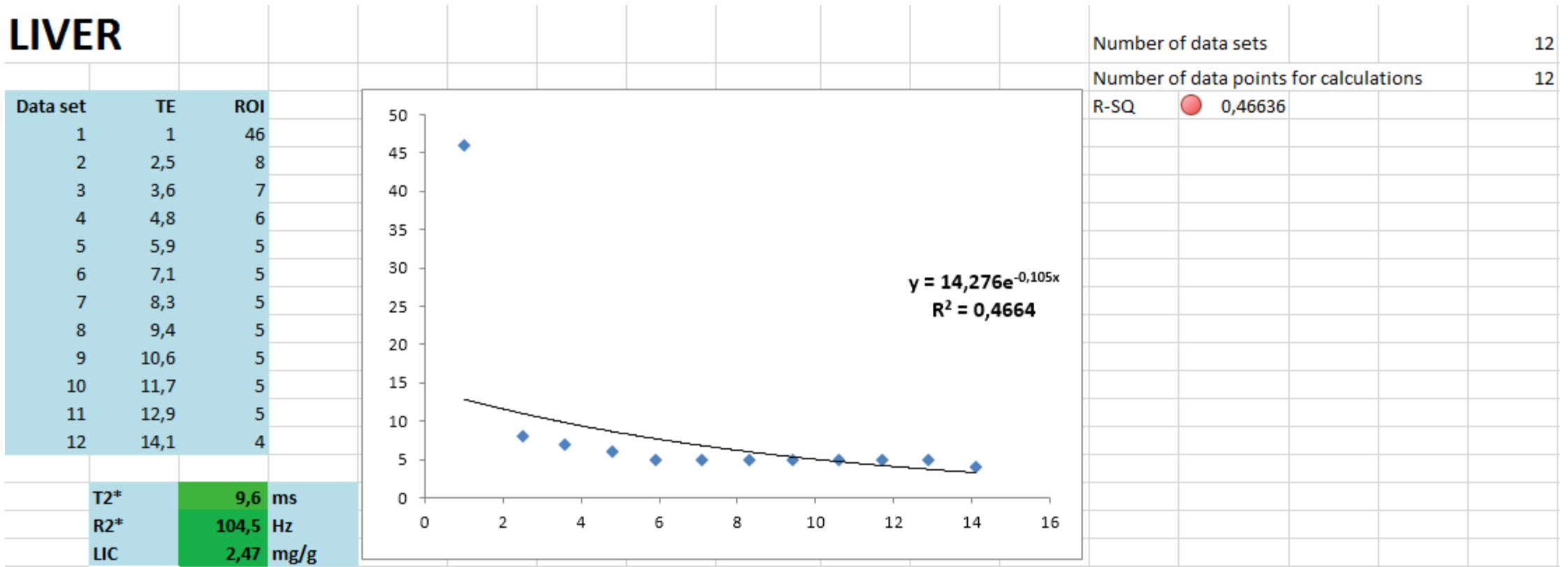

Fitting the data with 5 points
$R^2 = 0{,}9762$

Fitting the data with 4 points
$R^2 = 0{,}9972$

Too few numbers!

When there is too much iron in the liver (LIC >30 to 35 mg/g) you have reached the limit of the T2* method.
This will generate curves like this:

LIVER

Data set	TE	ROI
1	1	46
2	2,5	8
3	3,6	7
4	4,8	6
5	5,9	5
6	7,1	5
7	8,3	5
8	9,4	5
9	10,6	5
10	11,7	5
11	12,9	5
12	14,1	4

T2*	9,6	ms
R2*	104,5	Hz
LIC	2,47	mg/g

Number of data sets: 12
Number of data points for calculations: 12
R-SQ: 0,46636

$y = 14{,}276e^{-0{,}105x}$
$R^2 = 0{,}4664$

LIC very low – severely underestimated if trying to fit all points!

Too few numbers – how to correct

- Reacquire the images with the lowest TE possible (the lower the better)
- If already very low TE (as in this case TE1 = 1.0ms), use just two or three points. This will overfit your data and give you a less accurate number. Some centers just report LIC above 30mg/g threshold for example.
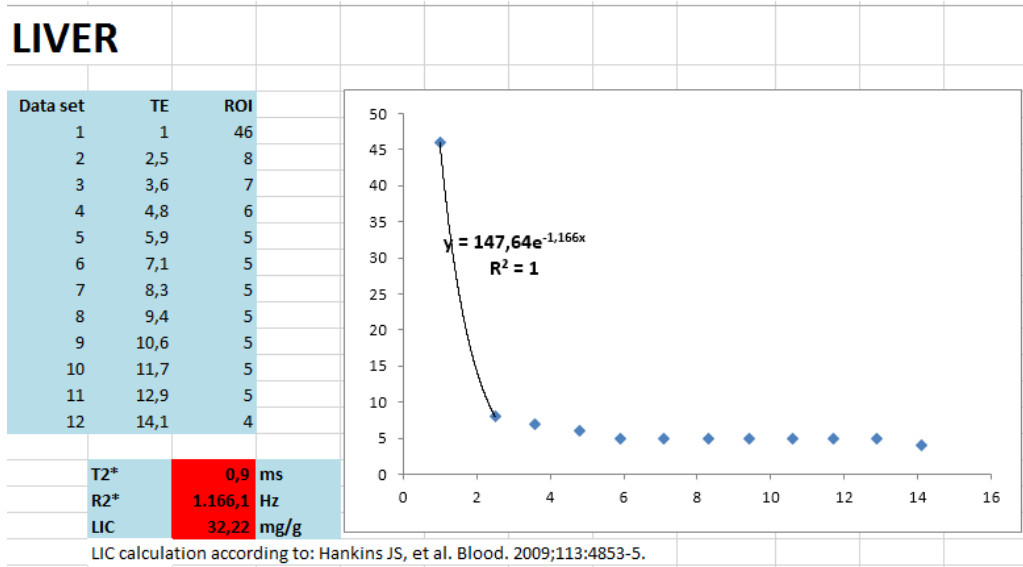
2 points only – overfit, but more accurate result

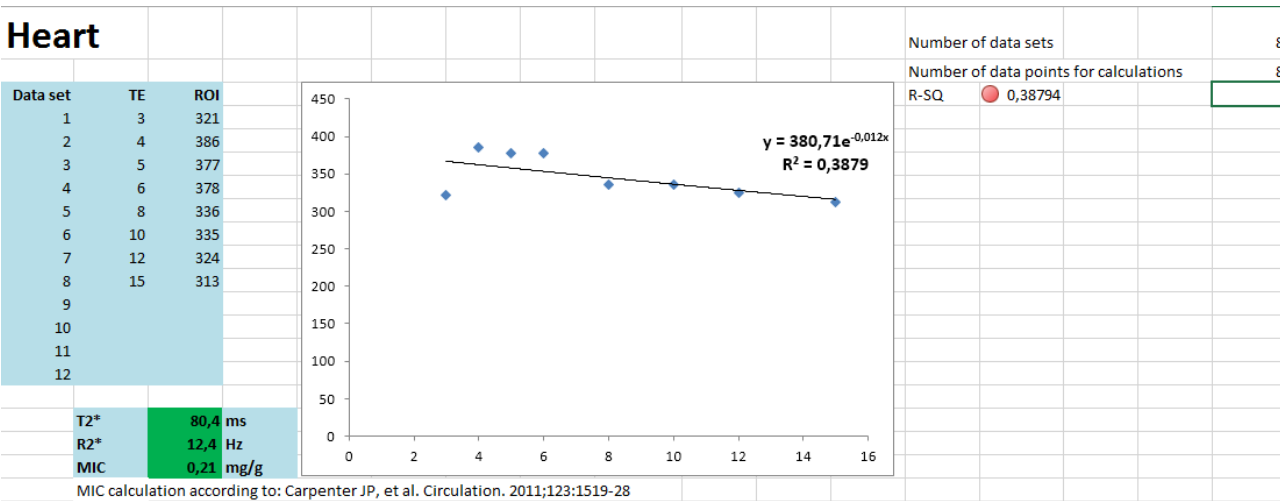Report: LIC > 30mg/g (above upper limit of the method)
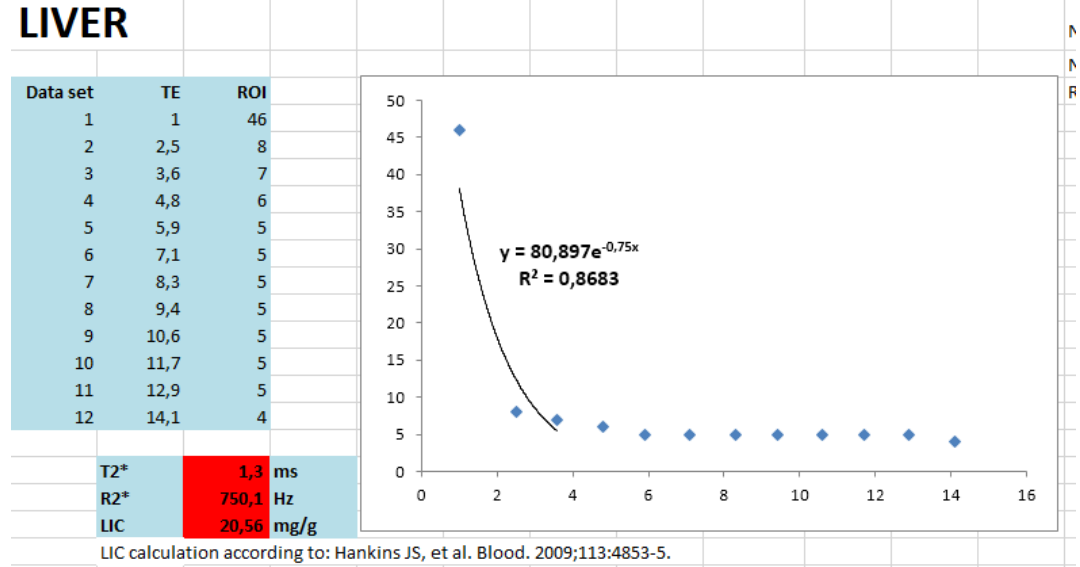
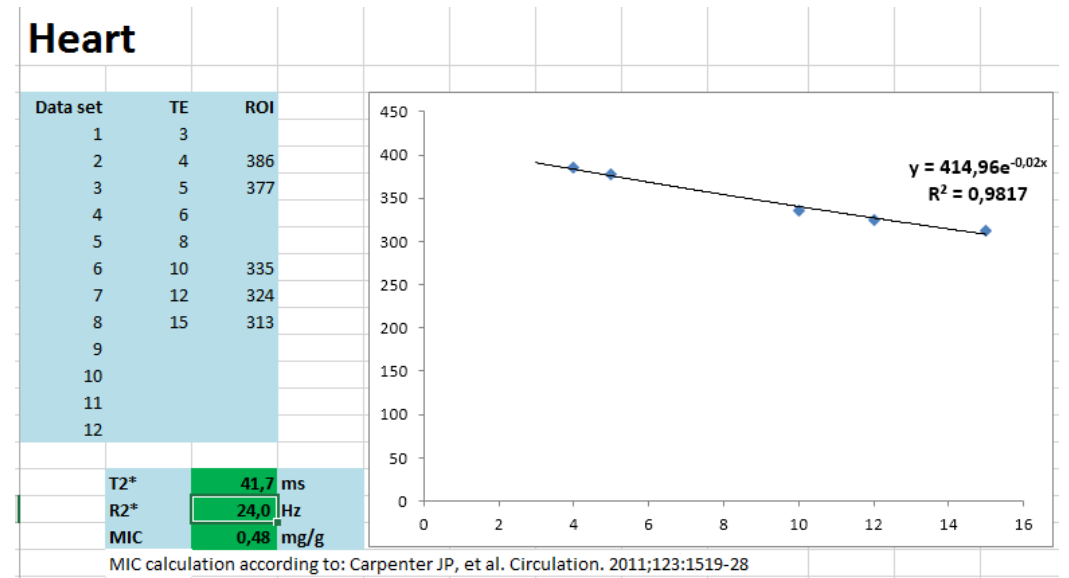3 points – still poor fit, with $R^2 = 0,87$ only

Bad images

This case generated very noisy/moving images of the heart. Ideally this should be rescanned.
If not possible, delete points which look out of line. Nevertheless, signal drop very slow, so certainly classified as > 20msec.

Heart

Data set	TE	ROI
1	3	321
2	4	386
3	5	377
4	6	378
5	8	336
6	10	335
7	12	324
8	15	313
9		
10		
11		
12		

T2*	80,4	ms
R2*	12,4	Hz
MIC	0,21	mg/g

Number of data sets	8
Number of data points for calculations	8
R-SQ	0,38794

$y = 380{,}71e^{-0{,}012x}$
$R^2 = 0{,}3879$

MIC calculation according to: Carpenter JP, et al. Circulation. 2011;123:1519-28

Very high T2* - uncommon. Very poor fitting.

Heart

Data set	TE	ROI
1	3	
2	4	386
3	5	377
4	6	
5	8	
6	10	335
7	12	324
8	15	313
9		
10		
11		
12		

T2*	41,7	ms
R2*	24,0	Hz
MIC	0,48	mg/g

$y = 414{,}96e^{-0{,}02x}$
$R^2 = 0{,}9817$

MIC calculation according to: Carpenter JP, et al. Circulation. 2011;123:1519-28

Manual exclusion of points 3 – 6 – 8. Better fitting.
T2* normal.

Further information

Principles explained here apply for all T2* analysis software, not only the spreadsheet

For further information, please contact me:

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