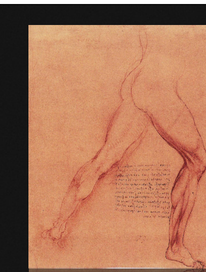
utcimaging

Welcome to the World of

UTC imaging

utcimaging



UTC imaging

novel approaches for the

Management of Tendinopathy

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edited October 2015

UTC imaging

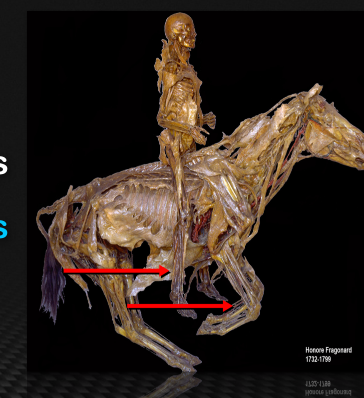
= Ultrasound Tissue Characterization

- ✓ standardized scanning
- ✓ visualizes & quantifies 3-D Tendon Integrity
- ✓ operator-independent
- ✓ highly reproducible
- ✓ discriminates various pathological stages
- ✓ sensitive to detect load effects

UTC stands for ultrasound tissue characterization.
The technique is based on completely standardized scanning.
It visualizes and quantifies 3-D tendon integrity.
It discriminates a variety of pathological stages.
It’s sensitive to detects load effects within one day.
And, most important, in contrast to conventional ultrasonography, UTC is objective, operator-independent and highly reproducible.

UTC imaging, from Horse to Man

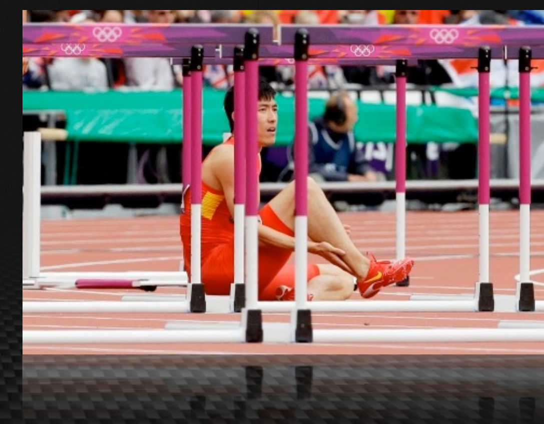
- since 1989 fundamental research, algorithms on isolated equine tendons
- 2001 clinical validation in equine sports orthopaedics
- 2004 clinical validation in human sports orthopaedics
- 2009 UTC Imaging company founded
- from 2010 cooperation with international research groups



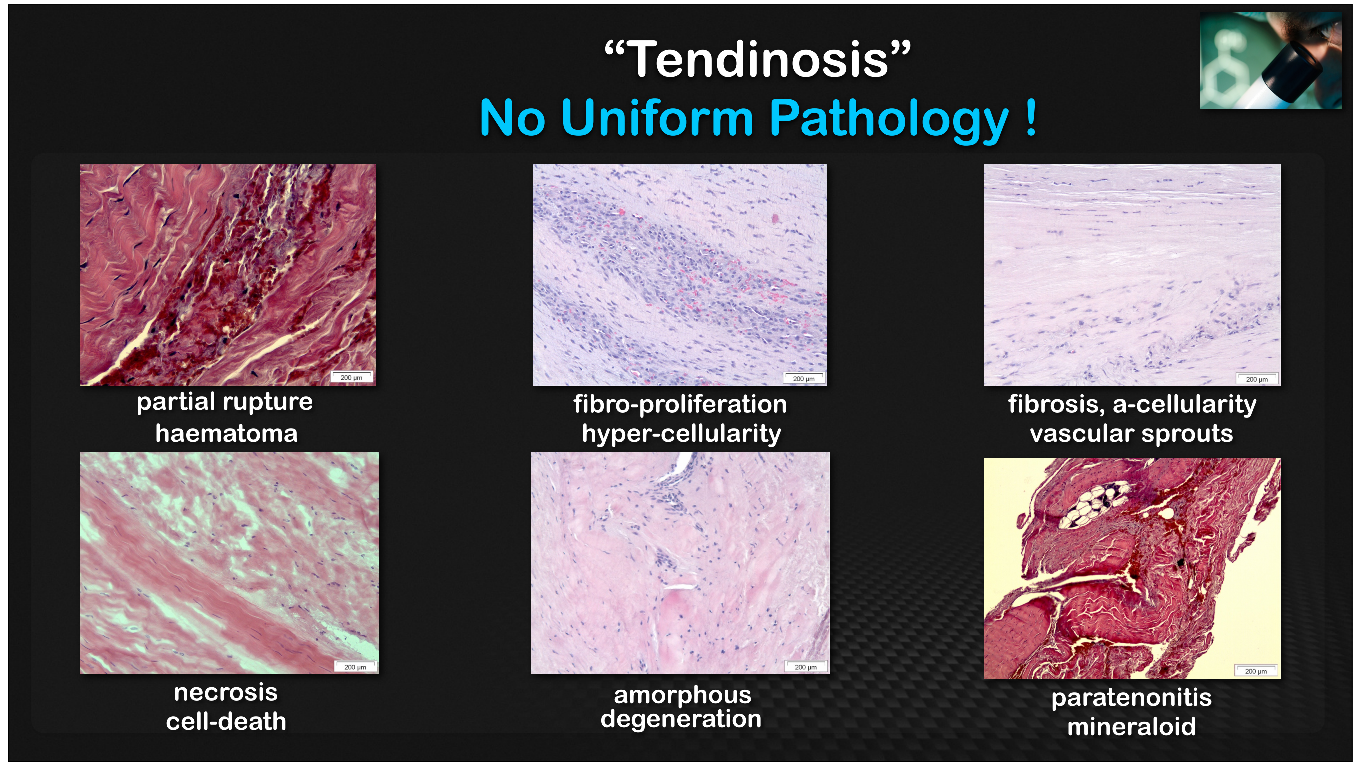
all about tendons

What is the Problem with Tendinopathy ?

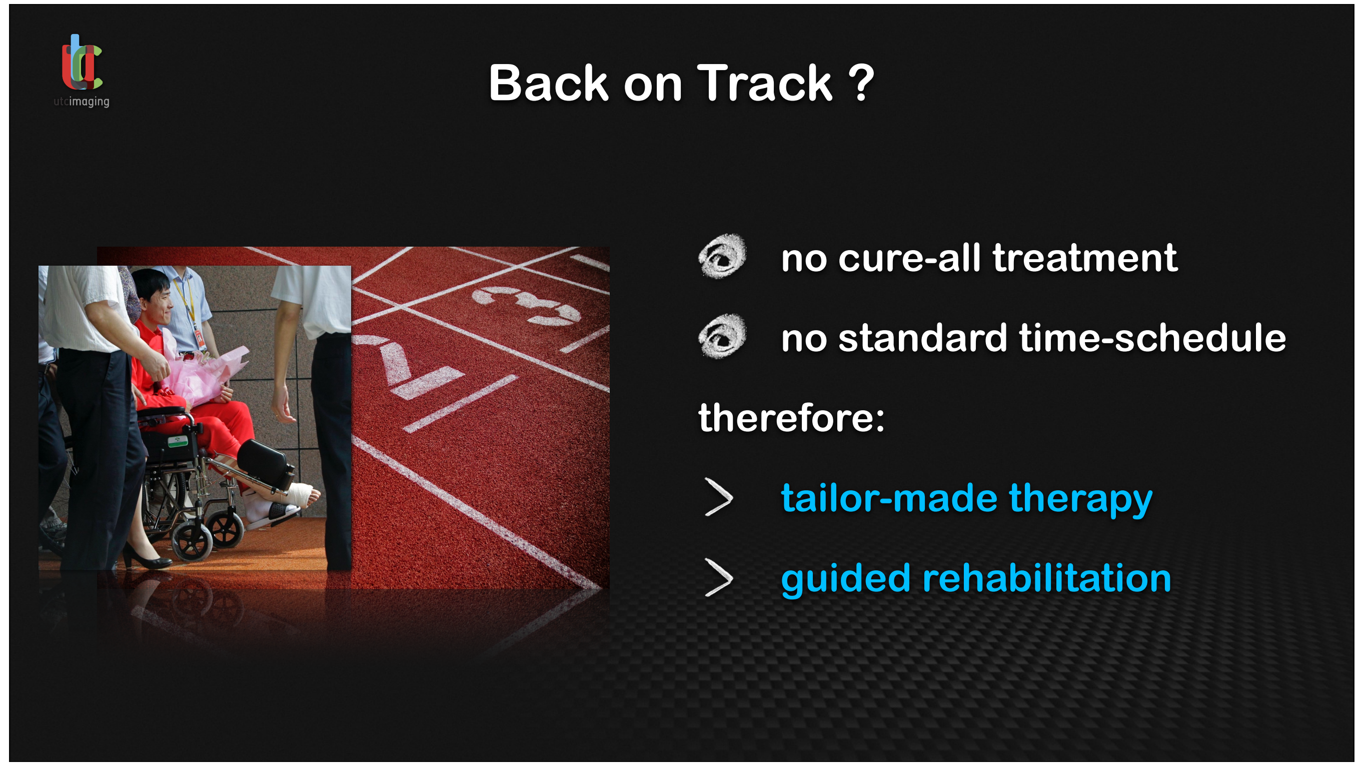
- insidious onset
- no one size fits all diagnosis
- no uniform pathology
- not a cure-all treatment
- slow recovery, at best



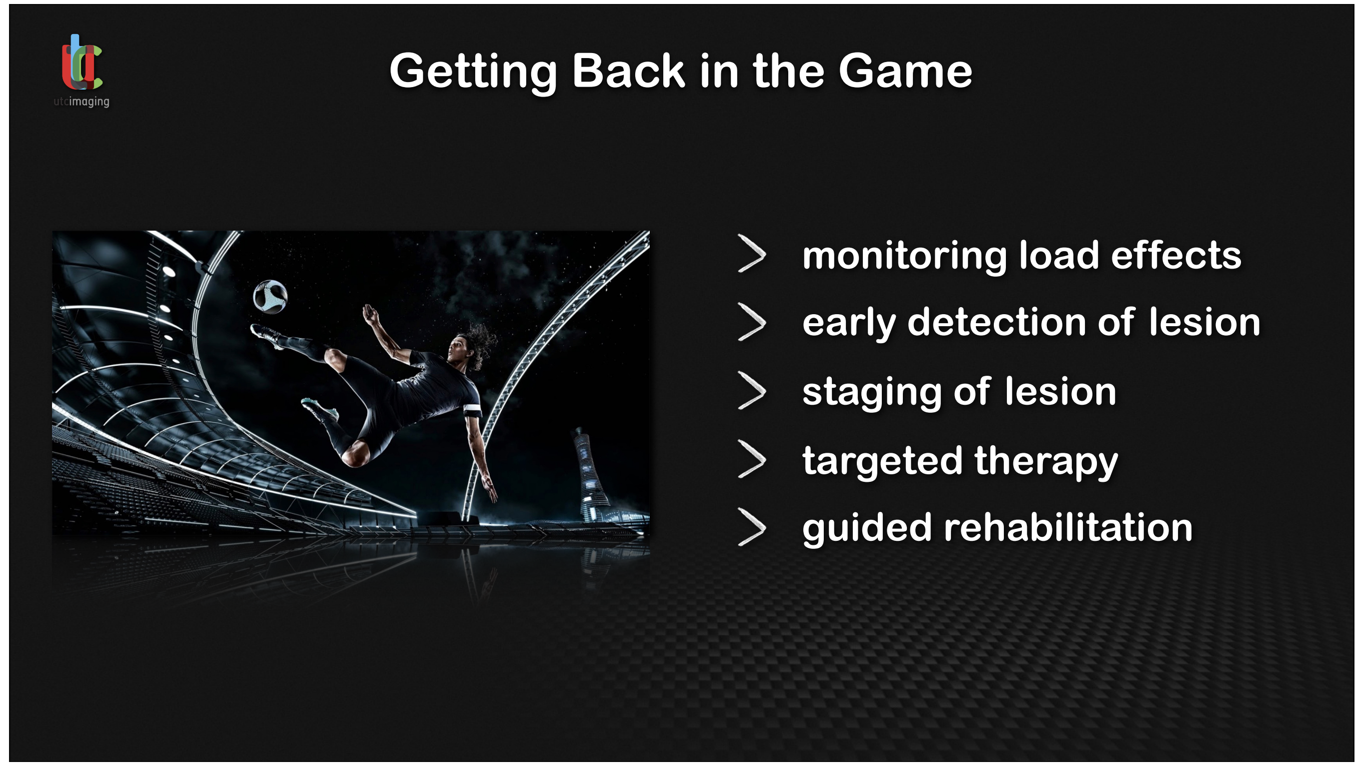
What is the problem with tendon injuries?
Most have an insidious onset, with degenerative changes developing initially without clinical signs.
It is not a simple,single stage diagnosis and therefore there is no cure-all treatment.
And there is a slow recovery, at best.



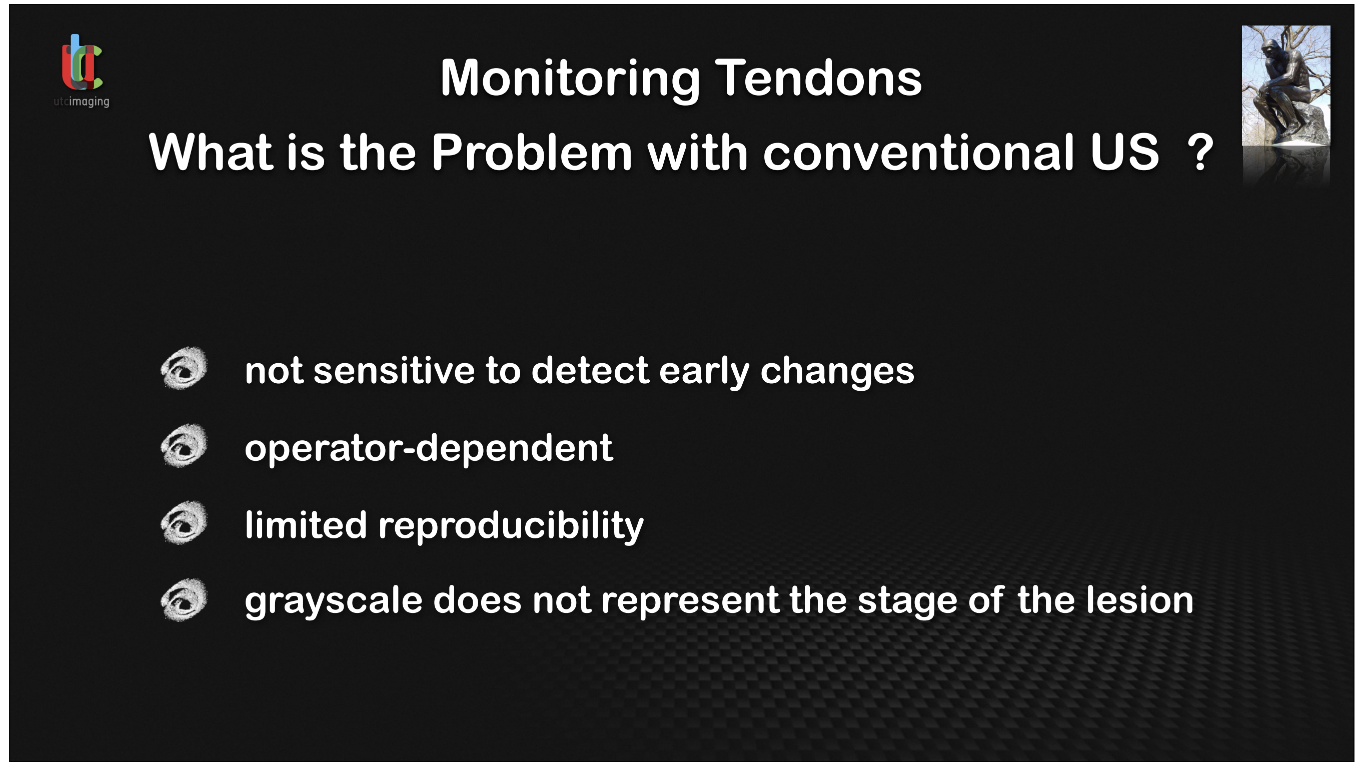
Tendinosis is no uniform pathology and tissue characterization may play a crucial role in prognosis and selection of treatment options.
Clinical symptoms are not related to specific histo-morphological characteristics, for instance, even in patients with long-lasting symptoms relatively recent changes can be observed.
On microscopy tendinosis may have many completely different features like:
* partial ruptures and haematoma,
* fibro-proliferation with hyper-cellularity and increased cell-metabolism.
* extensive disintegration with a-cellularity and vascular sprouts
* focal degeneration with cell-death and necrosis.
* amorphous mucoid, myxoid and fatty degeneration
* calcification
* paratenonitis



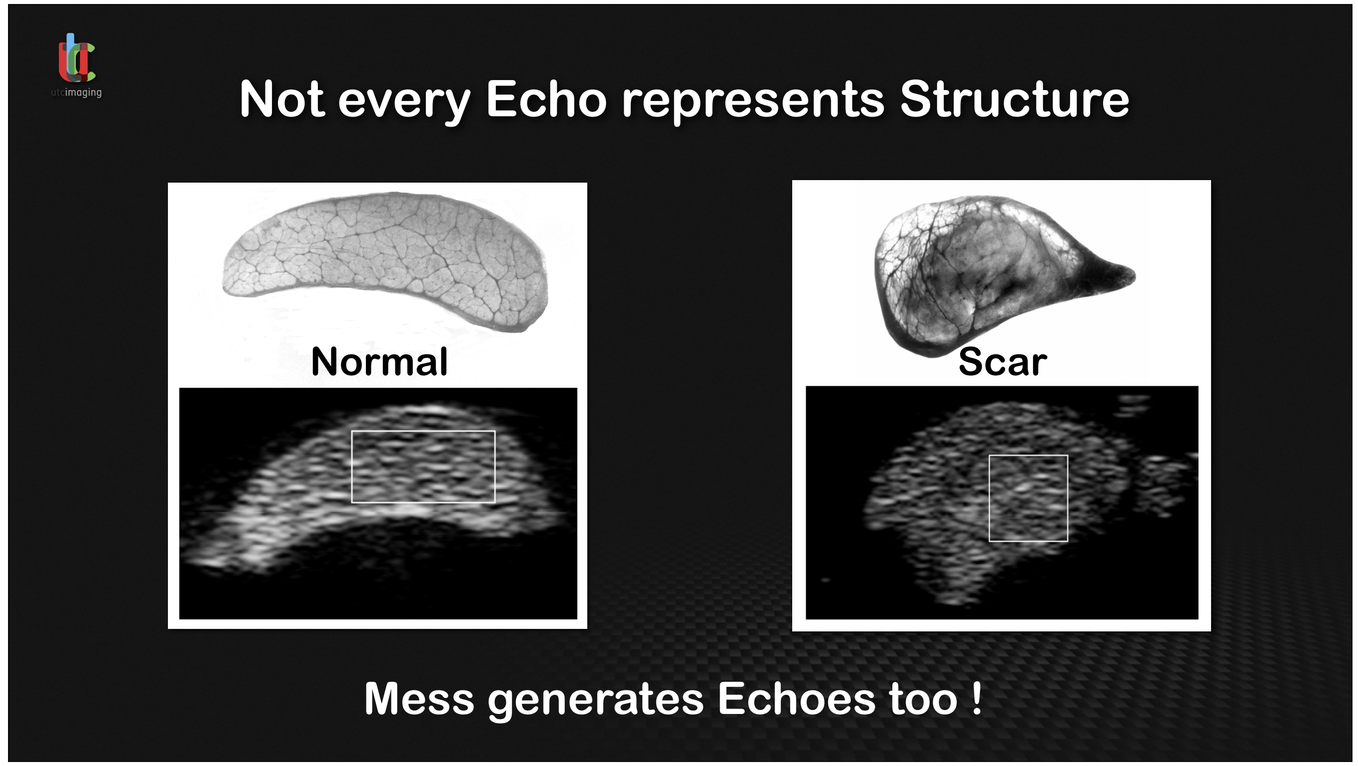
Return to sports can be hard: there is no cure-all treatment and there is no standard time-schedule for rehabilitation leading back to track.
To improve prognosis some major steps have to be made, such as:
tailor-made therapy and guided rehabilitation both based on staging of the injury.
This means to decide whether the injury is the result of single macrotrauma or that there is already underlying aging and/or pathology like fibrosis or degeneration.
Or to decide whether the lesion is still in fibro-proliferation or already in remodeling stage.
This allows tailor-made therapy which means the best therapy for the specific stage of the injury and of course for an optimal guided rehabilitation.



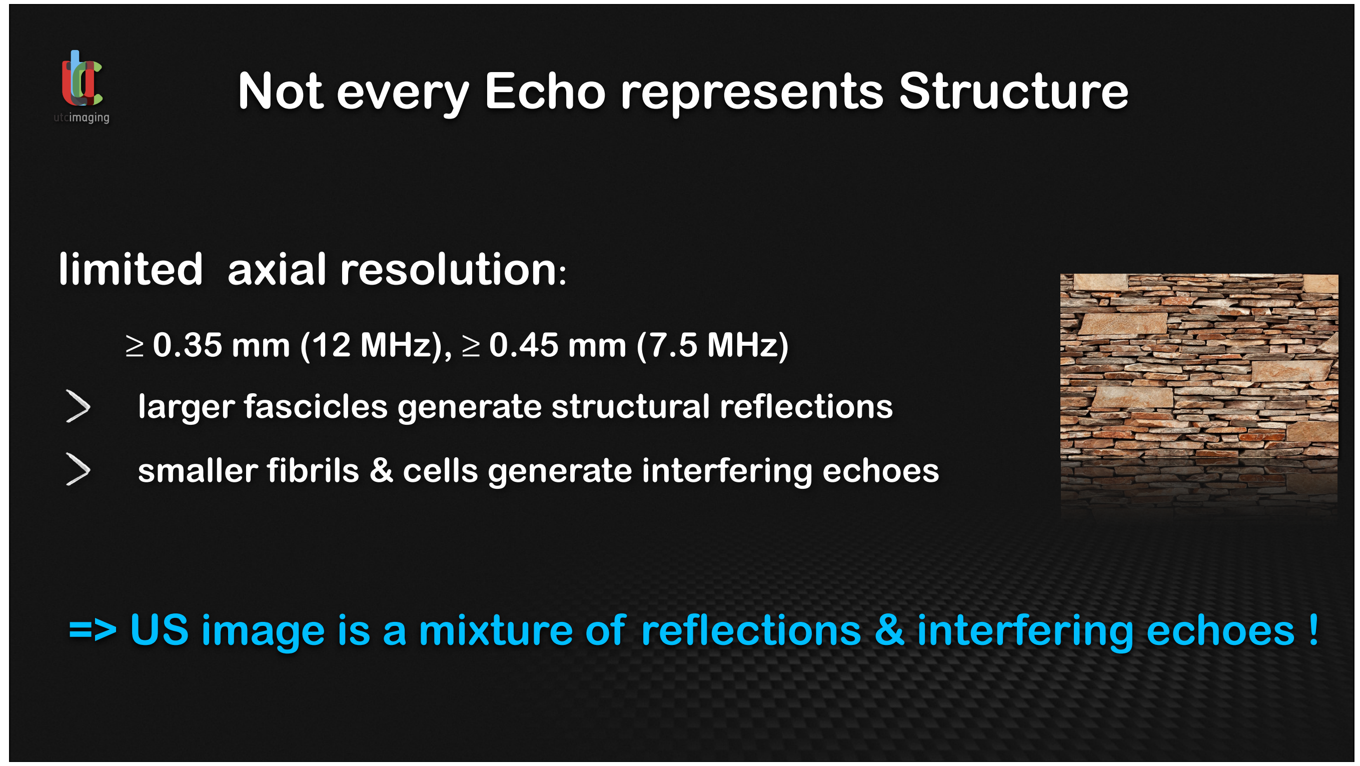
Major spearheads in the management of tendinopathy are:
monitoring load effects
early detection of matrix changes
staging of lesions
fine-tuned therapy
guided rehabilitation



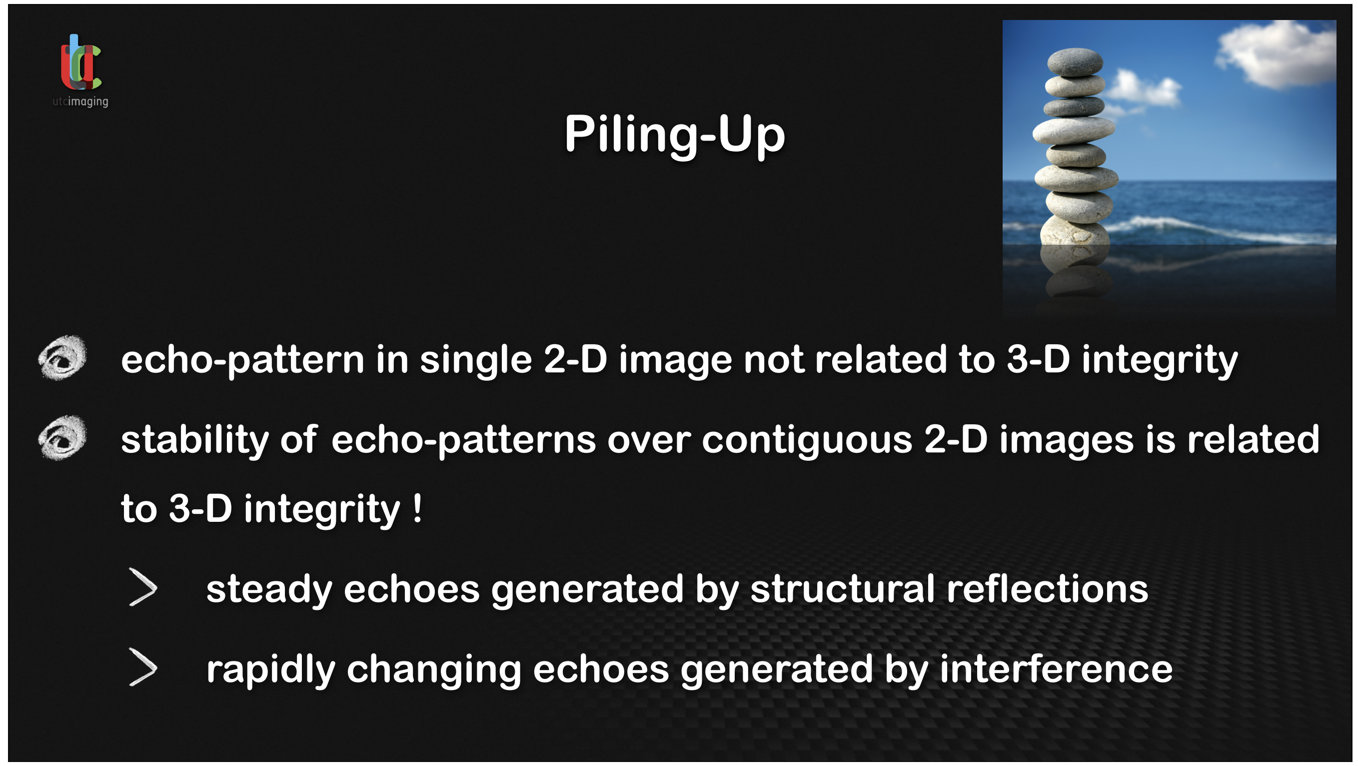
So, it would be good to monitor tendons.
Can conventional ultrasonography do the job?
Grayscale ultrasound is not sensitive enough to detect early changes in the tendon matrix.
Furthermore ultrasonography is highly operator-dependent and it suffers a limited reproducibility.
As shown in the next slides grayscale images don’t represent stage of integrity.
Therefore conventional ultrasound can not be used for reliable staging and monitoring of tendons.



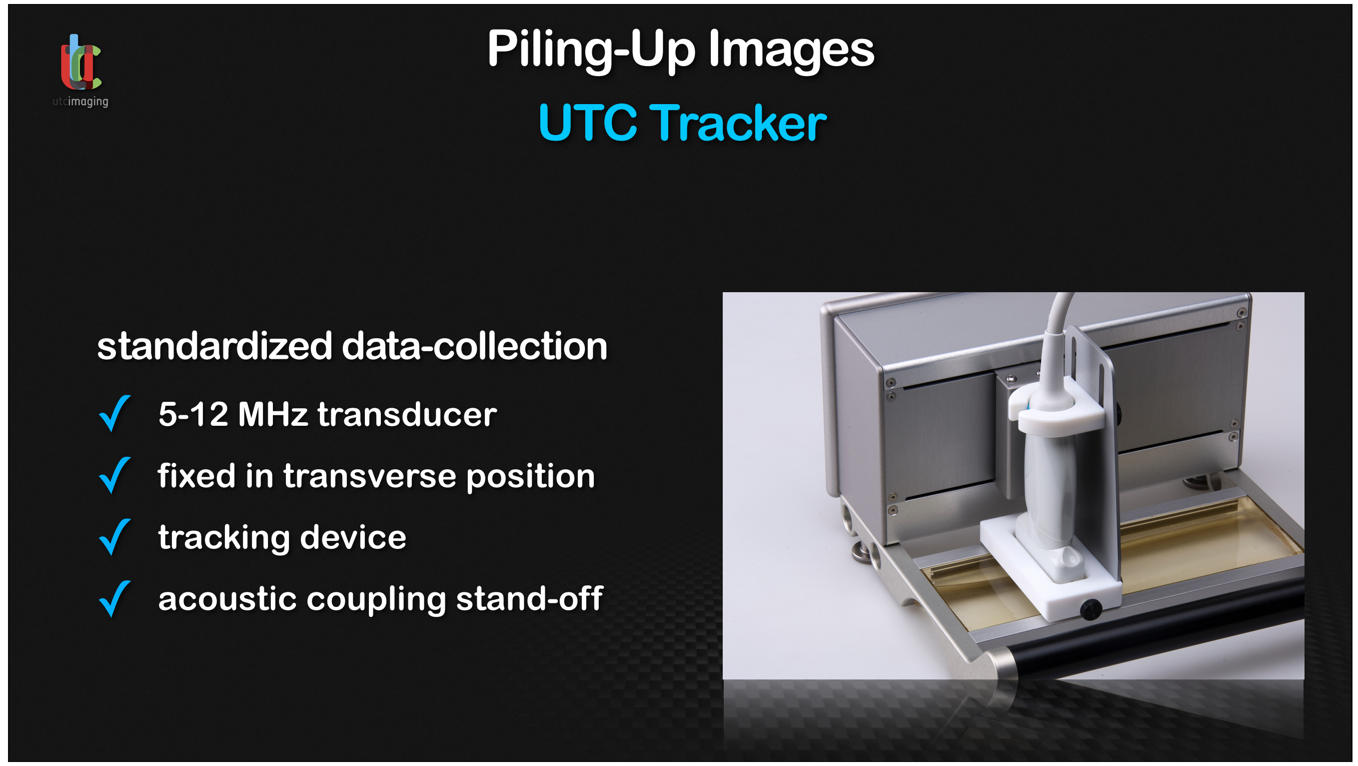
During fundamental research we matched ultrasonographic images exactly with post-mortem macro- and microscopy.
To the left a completely normal tendon and to the right a tendon with an extensive scar. Despite of the fact that the scar contains no normal structure at all, lots of echoes can still be found in the transverse ultrasonographic image.
The image on the right side clearly shows not only that scar tissue generates echoes but also that these echoes may have higher intensity (higher gray level) compared to the echoes generated by the relatively normal tissue in the periphery of the scar.
So, a mess without any structure can barely be discriminated from normal integrity in grayscale images.



Why is a grayscale image not discriminative for the stage of integrity.
To put it simple: compare the ultrasonographic image of a tendon with this wall of natural stone.
A tennis ball thrown against this wall will only return in a straight line when it hits a larger stone, what I call a structural reflection.
In case the same ball hits more than one, smaller and irregular, stone, the ball won´t come back in straight line, but he will break away and most probably will interfere with other returning balls.
Simply, the same happens in ultrasonography.
* in case an ultrasound wave hits a relatively large collagen bundle, a so-called fascicle, this single interaction generates a single structural reflection.
* on the other hand, in case an ultrasound wave hits more than one smaller entities like fibrils and cells, these multiple interactions generate multiple interfering echoes.
As such, the ultrasonographic is a mixture of structural reflections and interfering echoes which can not be discriminated by means of gray level/intensity in the ultrasonographic image.
Based on this fundamental research it can be concluded that gray levels in a 2-D image doesn’t represent 3-D matrix structure.



In the previous slide it was concluded that gray level in a single 2-D image doesn’t represent 3-D matrix structure.
However, while scanning meticulously along the tendon with the transducer in transverse position, the skillful ultrasonographer can evaluate the integrity based on the degree of stability of echo-patterns.
Normal tendons with normal ultrastructure consisting mainly of intact and aligned fascicles generate for the greater part structural reflections, leading to echo-patterns with high stability.
On the other hand, pathological tendons with a disorganized ultrastructure generate far less structural reflections, in favor of many more interfering echoes, leading a significantly less stability.
So, for a skillful ultrasonographer it is feasible to evaluate tendon integrity based on the stability of echo-pattern.
But this evaluation is poorly reproducible, operator-dependent and certainly not quantitative.
Quantification of ultrastructural integrity can be done by means of quantification of stability of echo-patterns over contiguous transverse images which requires precise compilation.

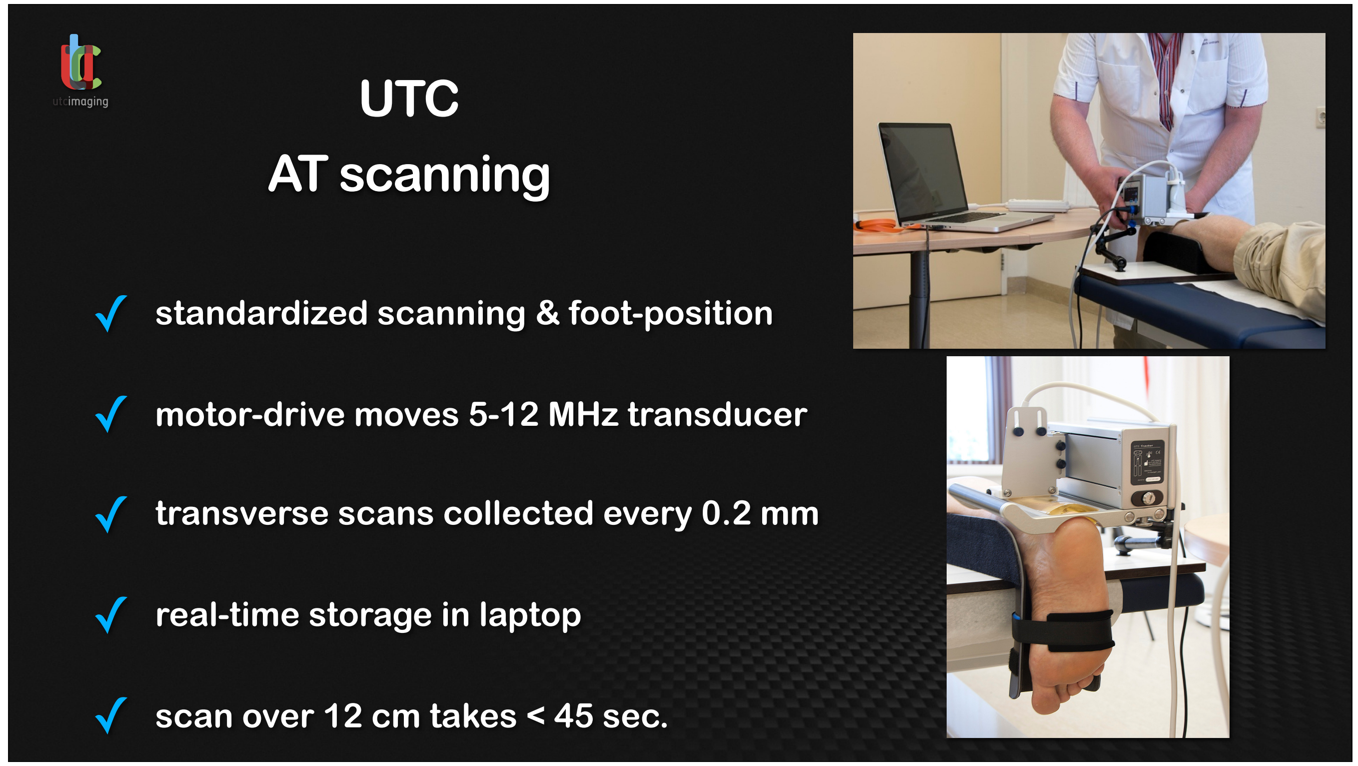


For quantification of the stability of echo-patterns over contiguous transverse images, a standardized and precise compilation of contiguous images is crucial. Therefore the UTC Tracker was developed.

It is portable modality completely different from conventional ultrasonography. The ultrasound transducer is not operated manually but fixed in transverse position in the tracking device, preventing transducer-tilt. The device also contains an acoustic coupling stand-off.

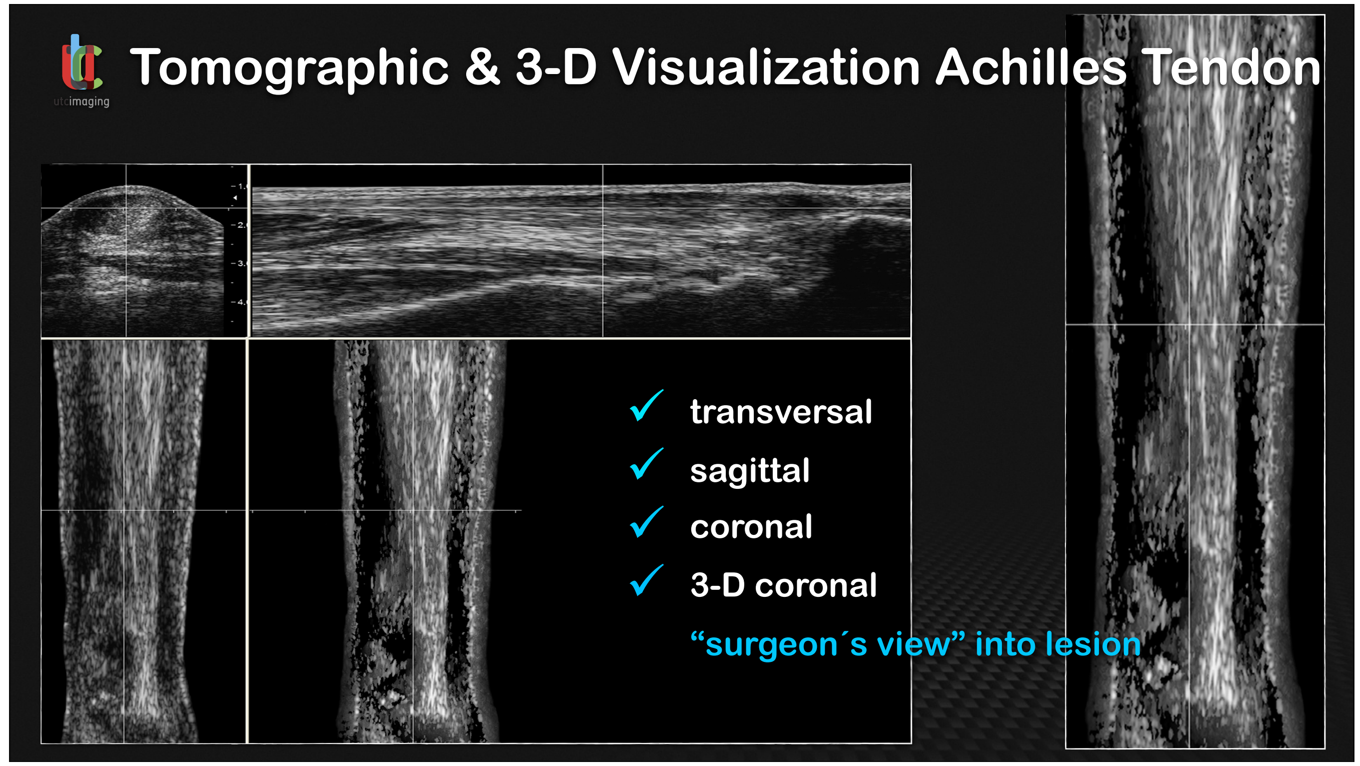
The tracking system is motorized for a gradual movement of the transducer.

And, during the sweep along the tendon transverse images are captured at regular distances of 0.2 mm and stored real-time in a high-capacity laptop computer.

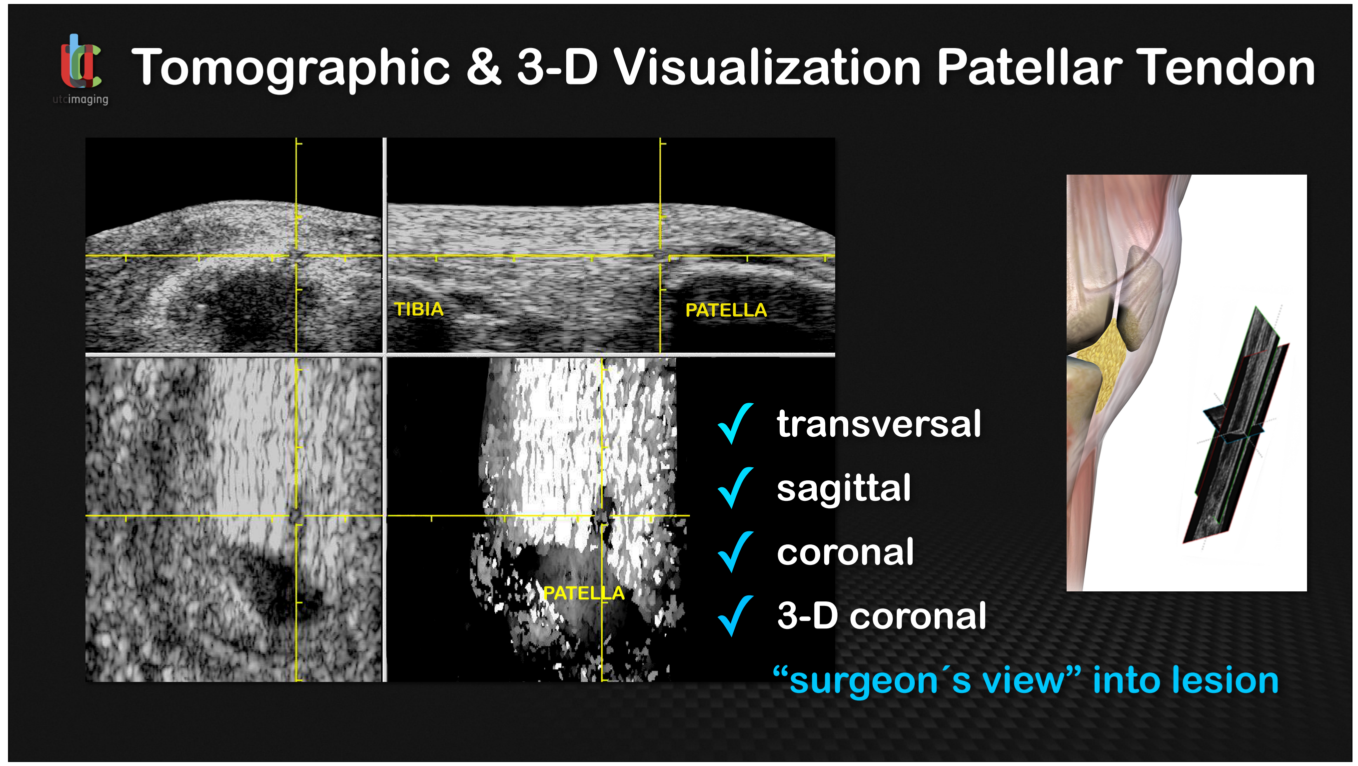


It is portable modality completely different from conventional ultrasonography
Foot position and data-collection are standardized.
Using the 5-12 MHz ultrasound transducer, for each specific tendon (e.g. achilles, patellar) standardized instrumental settings are designed, e.g. for frequency, depth, focal point, gain, TGC-curves. And all image processing is switched-off in order to collect the raw (non-processed) ultrasound data, for optimal resolution (both spatial and contrast).
The transducer is not operated manually but fixed in transverse position in a tracking device, preventing transducer-tilt. The device also contains an acoustic coupling stand-off.
The tracking system is motorized for a gradual movement of the transducer.
And, during the sweep along the tendon transverse images are captured at regular distances of 0.2 mm and stored real-time in a high-capacity laptop computer.
Scanning over 12 cm takes less than 45 seconds.
This guarantees that always and everywhere a tendon is scanned with exactly the same instrumental settings.

UTC scanning in clinical setting



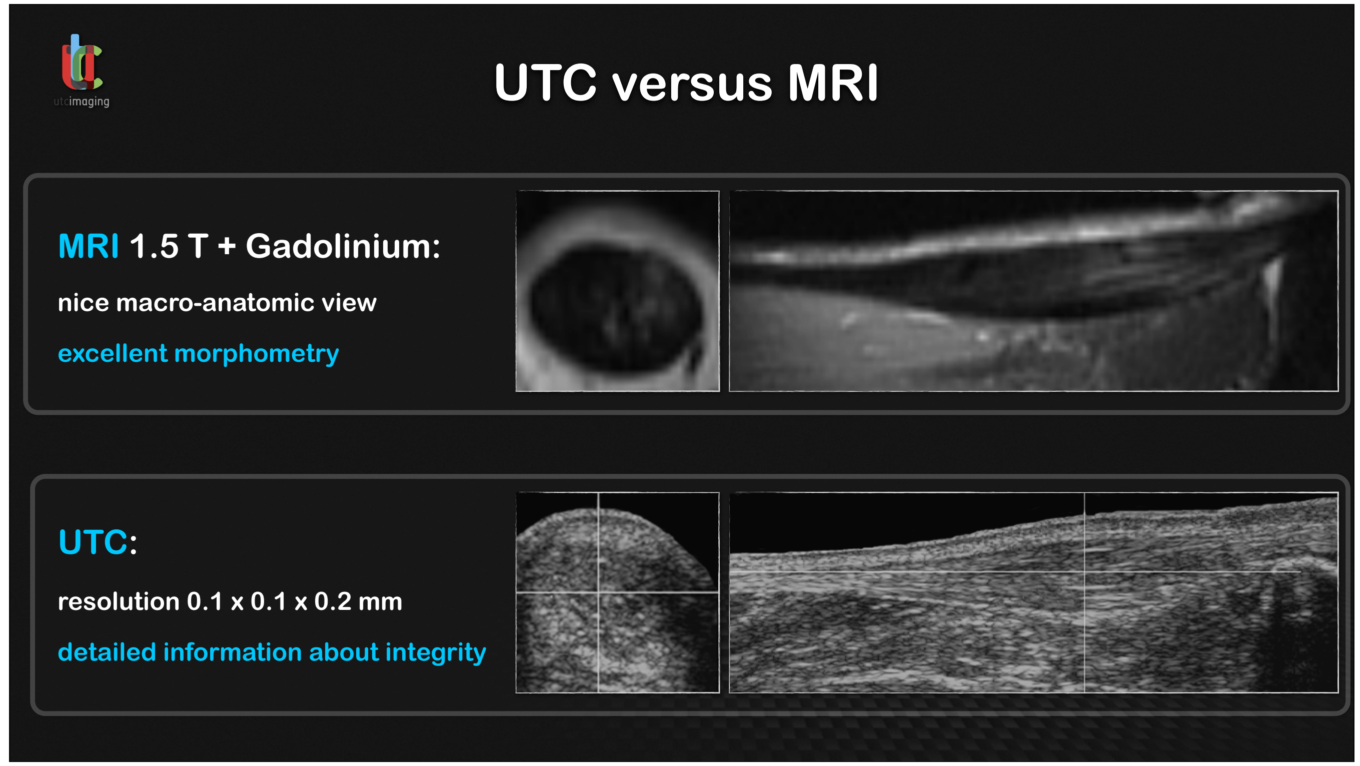
By piling-up and compounding these transverse images, tendons can be visualized tomographically in 3 planes of view, e.g. transversal, sagittal and coronal, and in a 3-D coronal view.
As mentioned before in slide 14, all image processing is switched-off in order to collect the raw ultrasound data. This results in optimal resolution (both spatial and contrast) and highest efficiency of UTC Algorithms for tissue characterization (see slide 19).
Please notice the 3-D coronal view, providing an inward view into the lesion, that can be used for planning local infiltrations or minimally-invasive interventions.
In this case the 3-D coronal image, right side, reveals mineraloid in the insertion on the calcaneus.



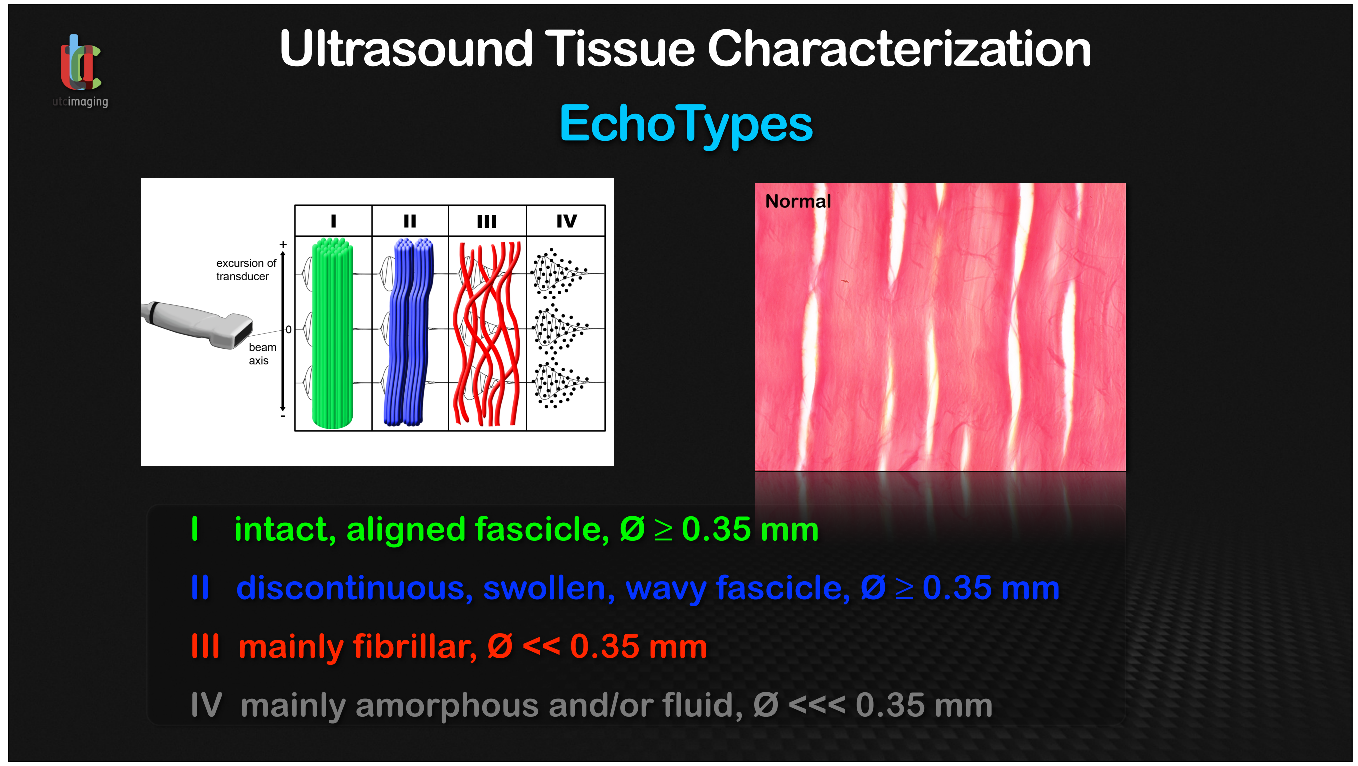
By piling-up and compounding these transverse images, a 3-dimensional volume block is created.
In this way tendons can be visualized tomographically in 3 planes of view and in 3-D.

* transversal
* sagittal
* coronal
* 3-D coronal image

As mentioned before in slide 14, all image processing is switched-off in order to collect the raw ultrasound data. This results in optimal resolution (both spatial and contrast) and highest efficiency of UTC Algorithms for tissue characterization (see slide 19).
Please notice the 3-D coronal view, providing an inward view into the lesion.
In this case a lesion in the patellar tendon at the inferior patella pole (in the 3-D coronal view the solid interface is the patella).



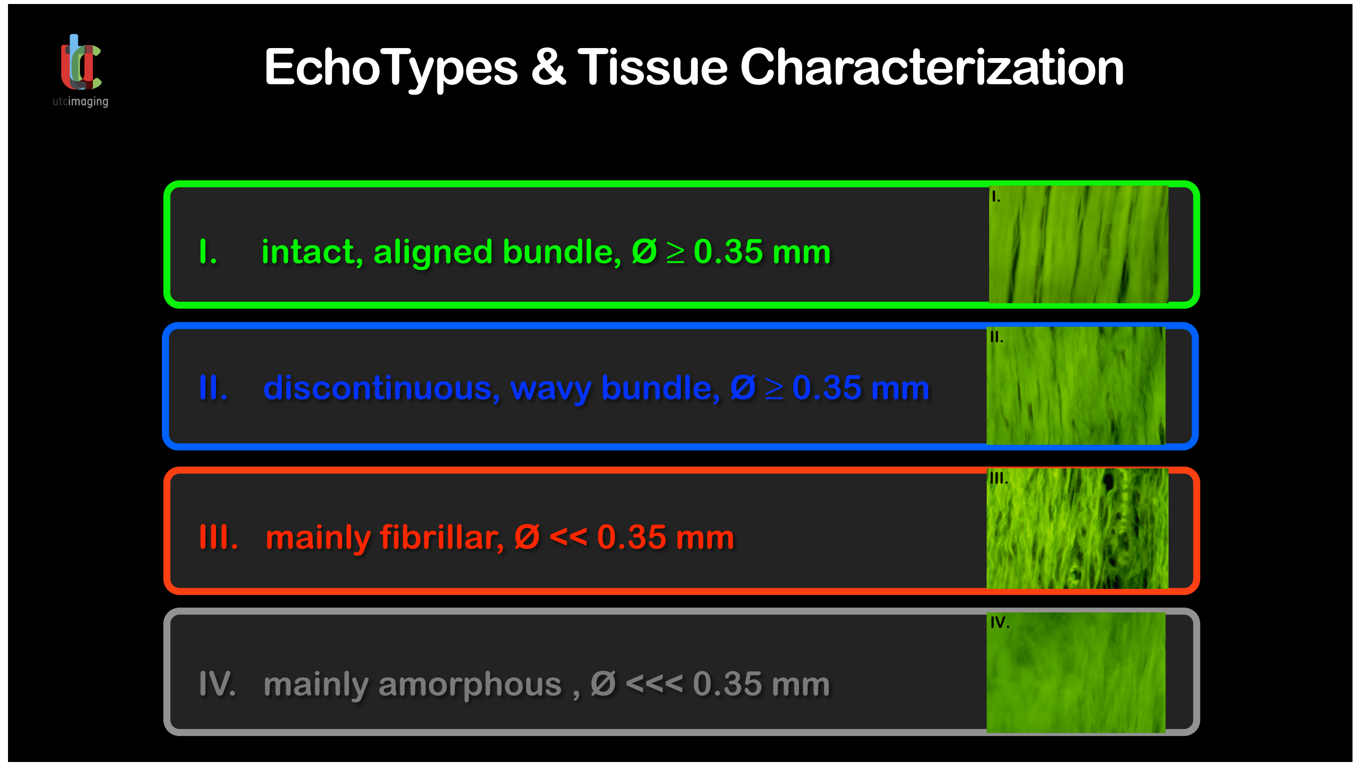
Spatial resolution of UTC was compared with 1.5 Tesla MRI, made with a dedicated protocol including Gadolinium contrast enhancement. Same patient, same day.
MRI offers a nice macro-anatomic view, facilitating excellent morphometry.
On the other hand it also evident that favorable spatial resolution of UTC visualizes tendon integrity with significantly more detail.



Even more important than visualization is tissue characterization and quantification of integrity.

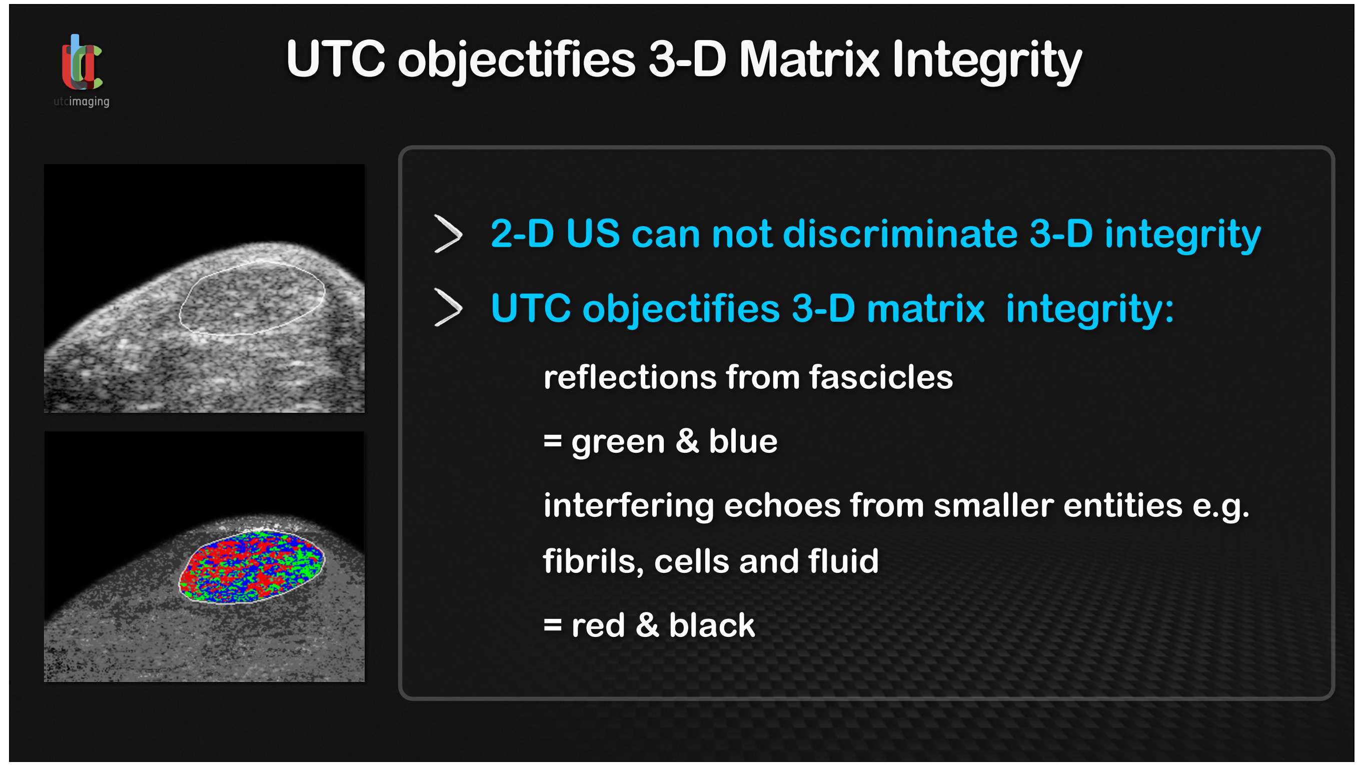
Based on the stability of echo-patterns in raw (non-processed) contiguous images UTC algorithms can discriminate 4 different echo-types, namely:
* type I, generated by intact and aligned secondary collagen bundles, so-called fascicles, colored green
* type II, generated by discontinuous, swollen and wavy secondary collagen bundles (fascicles), colored blue
* type III, related mainly to smaller fibrils, colored red, and
* type IV, related mainly to amorphous tissue with cells and fluid, colored black.

Please notice that echo-types I and II are generated by “structural reflections” from larger structures with axial diameter above spatial resolution (which means only 1 large interface within sample volume), while III and IV are “interfering echoes” from smaller entities below limits of spatial resolution (this means more, even many more, than just one smaller interfaces within the sample volume). See slide 11.

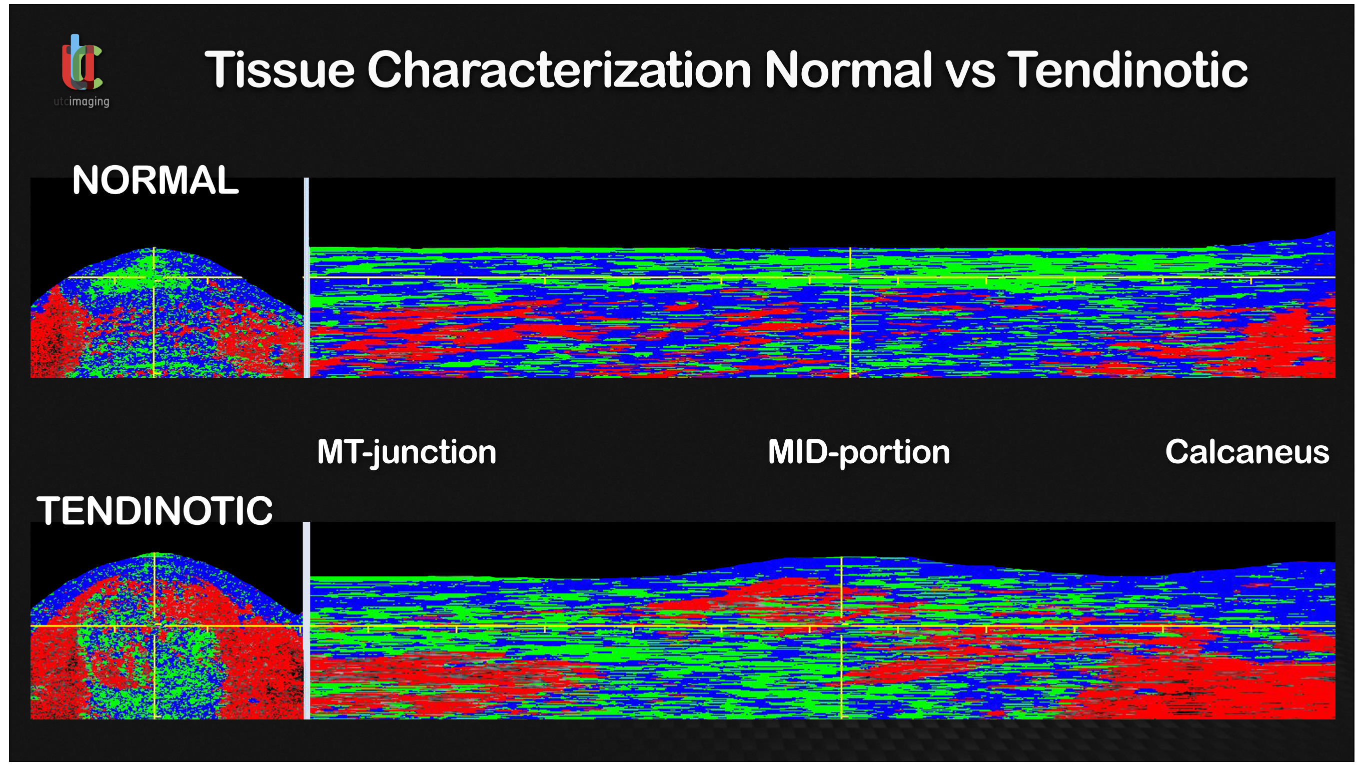


This slide show the relationship between discriminated echo-types and the underlying tissue-types:

* echo-type I generated by intact and aligned secondary collagen bundles, so called fascicles
* echo-type II generated by discontinuous, swollen and wavy fascicles
* echo-type III generated by a loose matrix consisting of much smaller fibrils
* echo-type IV generated by a mainly amorphous matrix



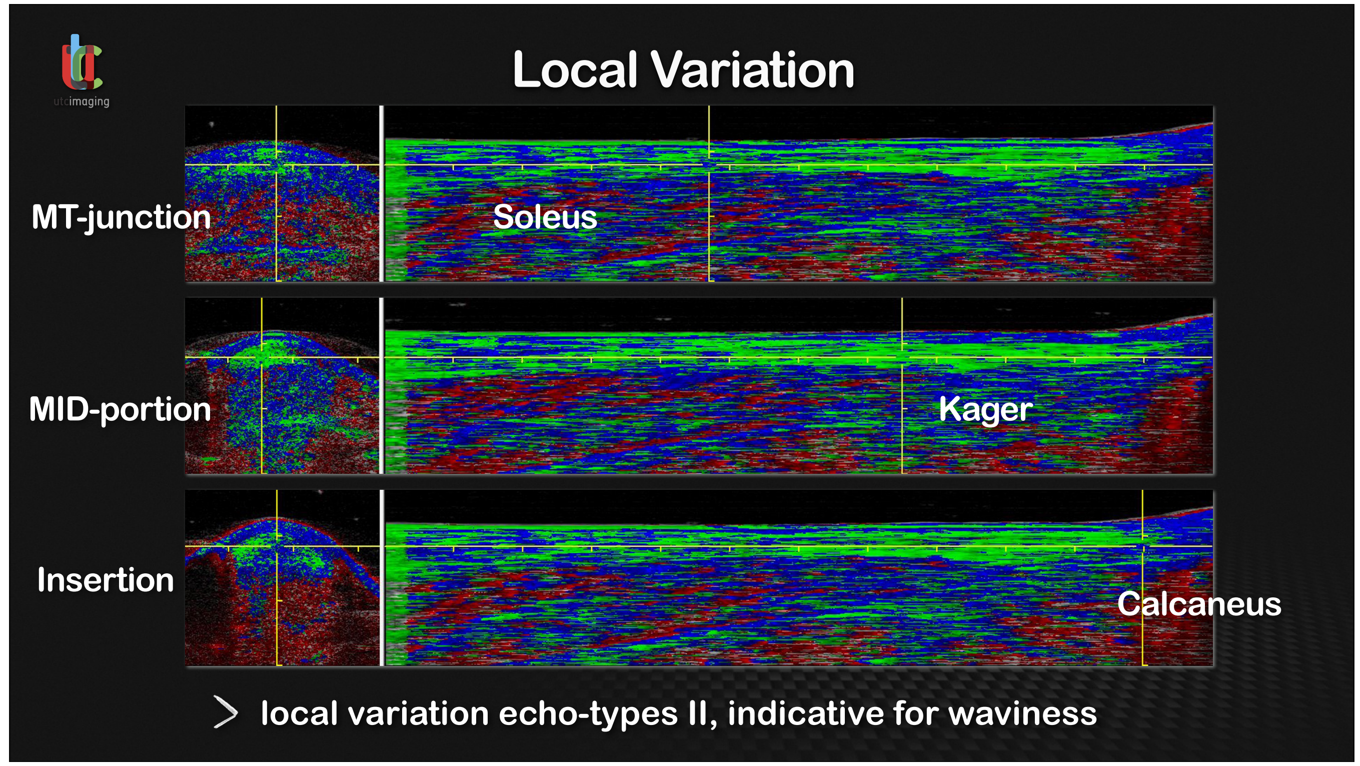
This slide with grayscale and UTC images of exactly the same tendon segment shows the benefits of UTC-processing.
Grayscale in 2-D images doesn't reflect 3-D integrity as a consequence of the fact that gray levels do not reflect structural integrity. Therefore it is impossible to discriminate structural reflections, generated by larger structures like fascicles, from interfering echoes, generated by smaller entities like fibrils, cells and fluid.
As mentioned before, also mess generates echoes, even with gray levels (intensity) within normal limits. See slide 10.
In contrast to the conventional (B-mode) 2-dimensional image, the UTC-processed image is the result of many more piled-up images (over longer distance), creating a volume and thus providing 3-dimensional information. Only larger structures like fascicles that are intact over longer distances will be colored green or blue while smaller and disorganized fibrils and cells will be colored red and black. In this way the lesion can be discriminated and its structural integrity can be quantified.



Already at first sight the substantial difference between a normal and a tendinotic Achilles tendon becomes visible, both in the transversal and in the sagittal plane of view.

The mid-portion of normal tendon consists mainly of echo-type I, usually 80-85 % (green, indicative for intact and aligned fascicles) and diffusely-distributed approximately 10-15 % echo-type II (blue, indicative for waving fascicles).

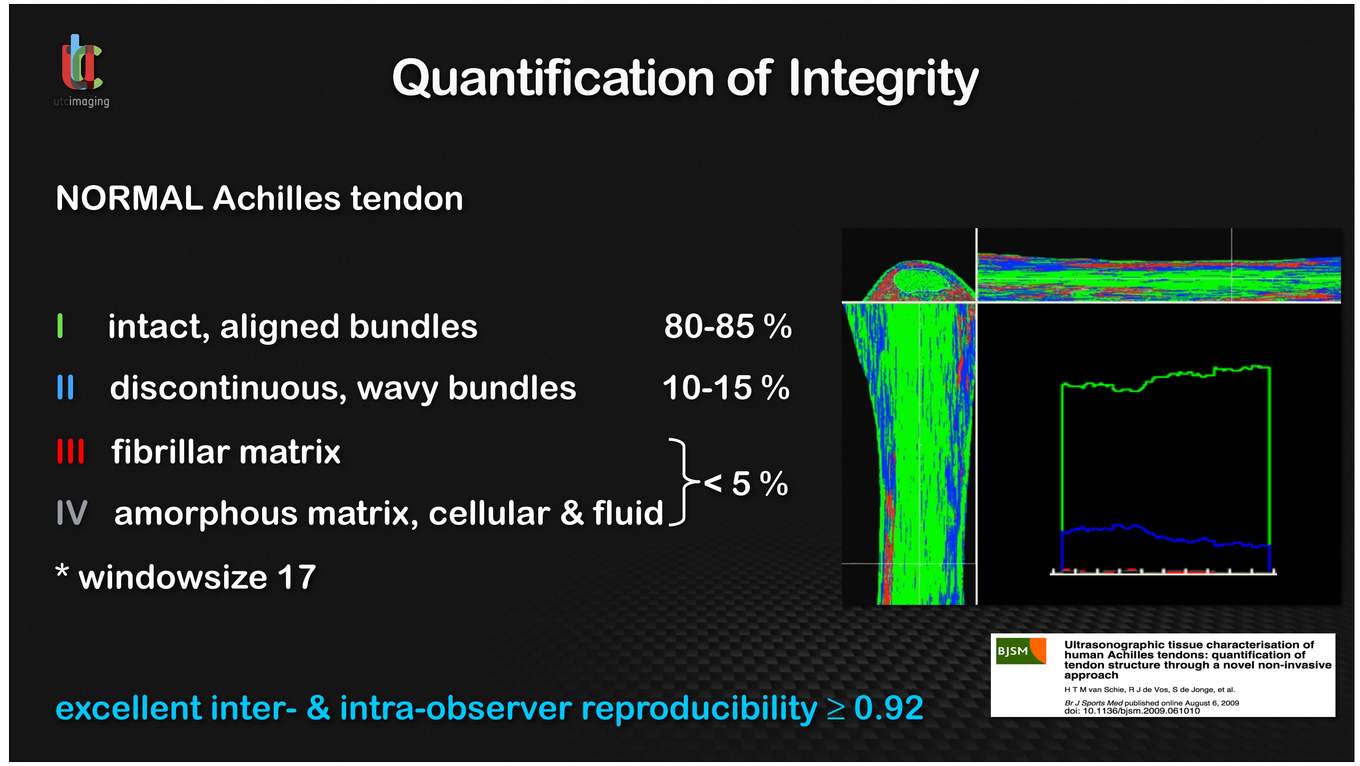
The mid-portion of a tendinotic tendon shows significant increases of echo-type III (red, indicative for fibrillar matrix) and/or IV (black, indicative for amorphous matrix and/or fluid). Also a significant increase of echo-type II (blue), mostly focally, can be observed which is indicative for discontinuous and poorly-aligned fascicles, frequently persistent in cases of fibrosis and degeneration, indicative for chronic pathology.



This fusion view (multiple layers, superimposed) clearly distinguishes the tendon proper from surrounding paratenon, soleus muscle, Kagers fatpad.

Please notice that towards MT-junction and insertion on Calcaneus an increase of echo-type II can be observed: this is physiological, as consequence of increasing waviness of fascicles.

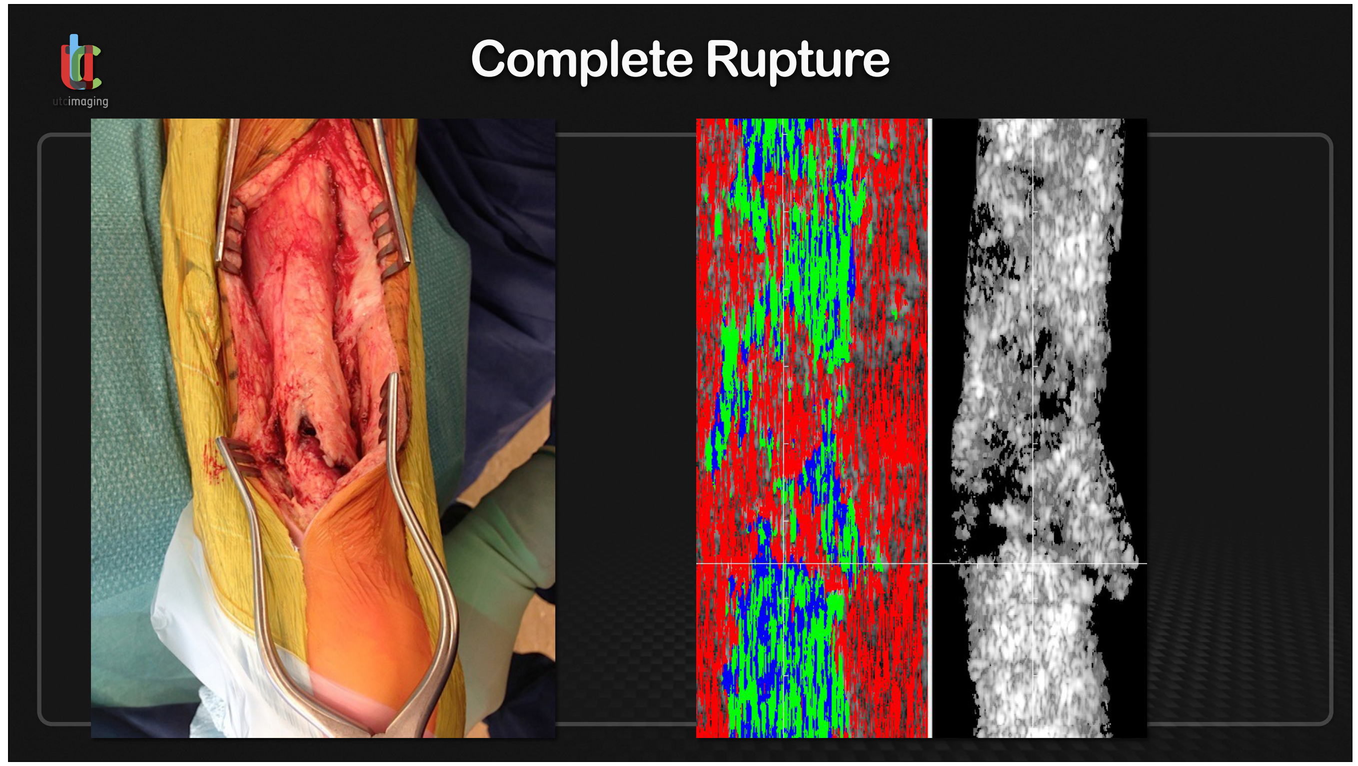
About increase of echo-type II, either physiological (see slides 30, 31) or pathological (see slides 32, 50, 51).



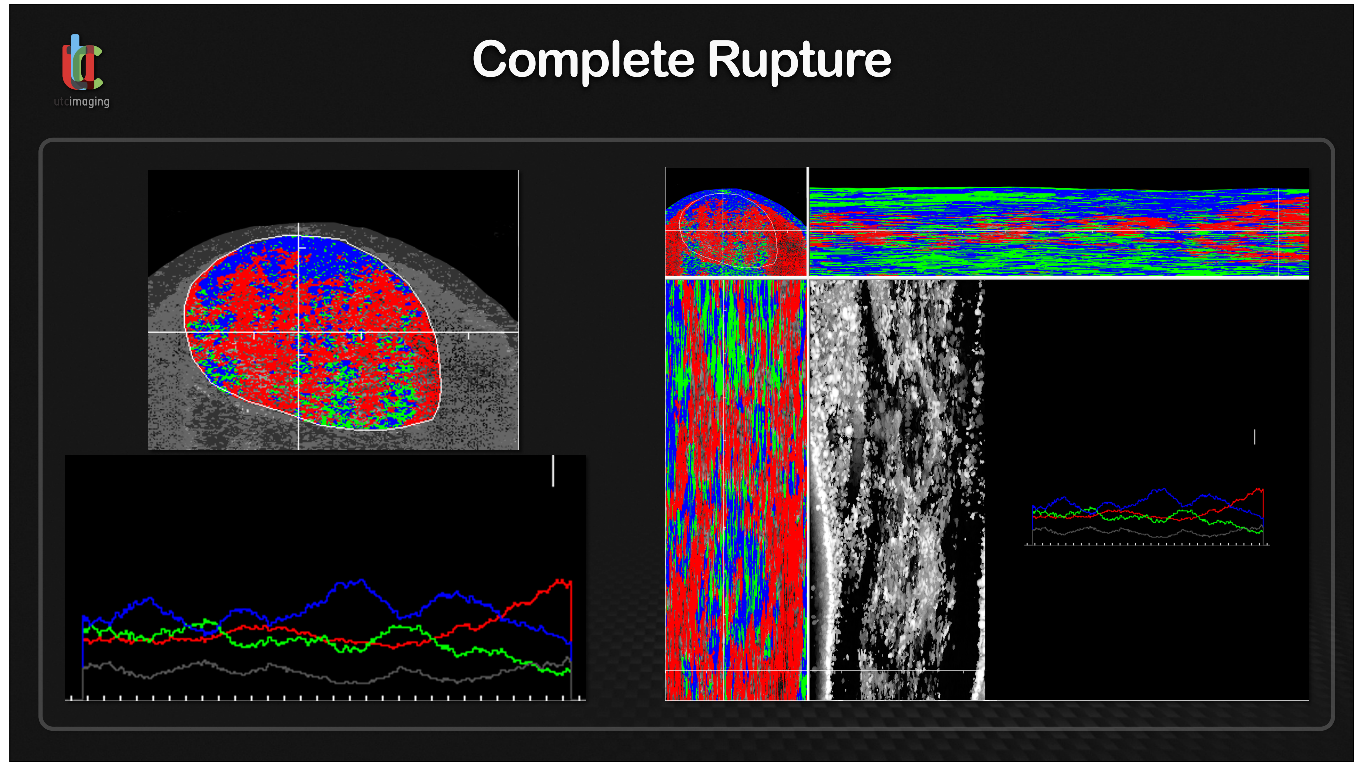
Tendon integrity can be quantified.
This is an example of a normal Achilles tendon, consisting of
* 80 till 90 percent echo-type I, and
* 10 till 15 percent echo-type II
Please notice: barely any type III or IV echoes.

About echo-type II, see slide 30: as a response to loads echo-type II may increase. As long as echo-type II is distributed diffusely over entire cross-section, this can be interpreted as physiological and in most cases reversible within days.

The inter- and intra- observer reproducibility is tested by several institutes, in clinical and in research settings, and all concluded that reliability is excellent.

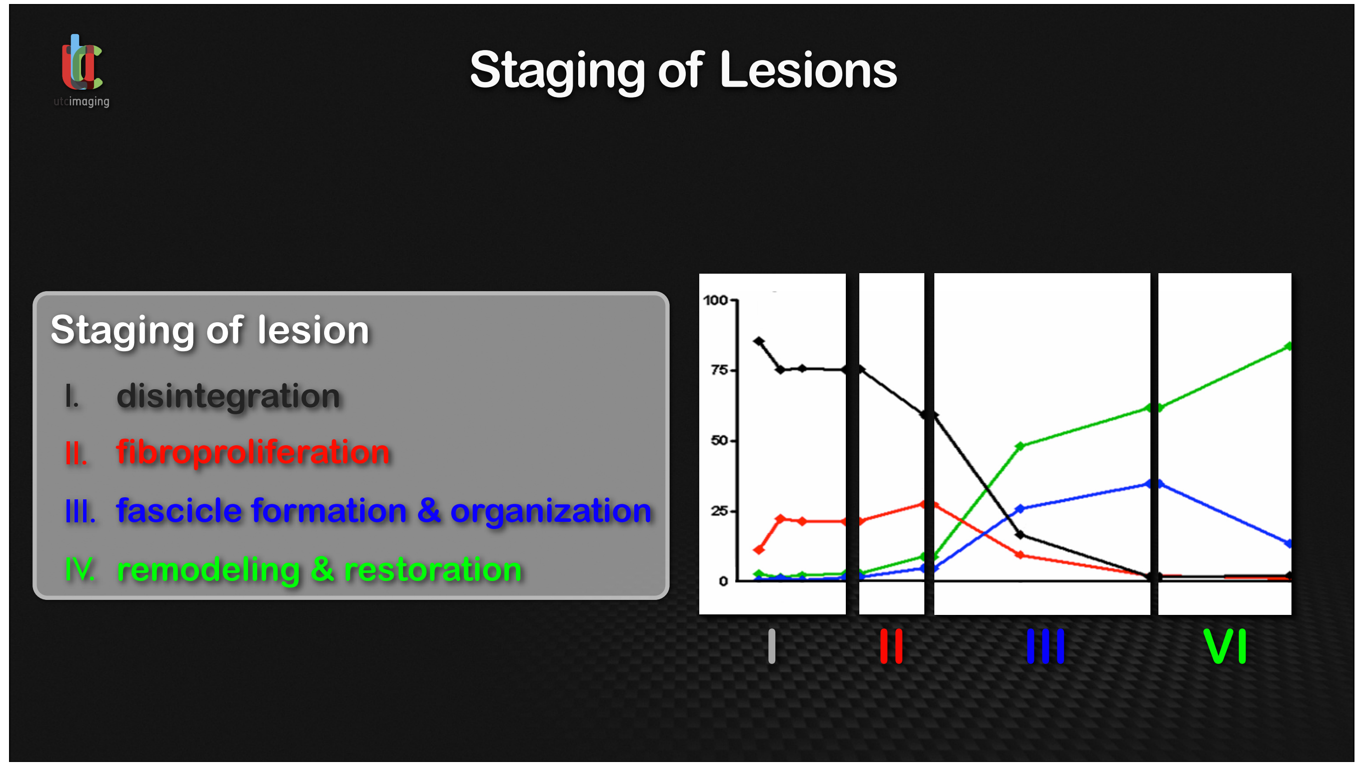


This is a case of a complete rupture in a world-champion athlete.
On the pre-surgery coronal views, the UTC imaging scan was made 1 hour prior to surgery, the rupture site is clearly visible. Especially the 3-D coronal view reveals the V-shaped rupture in great detail; indeed a surgeons view into the lesion.



This is another case of a complete rupture.
The degree of integrity in the entire tendon volume over 12 cm is quantified. As such the graph is a fingerprint of the current stage of integrity in the ruptured tendon.
There is a serious disintegration with:

* a sharp decrease of echo-type I, thus loss of intact fascicles
* a significant increase of echo-type II, indicative for many more discontinuous, disorganized and/or swollen fascicles
* a significant increase of echo-type III, indicative for the presence of a fibrillar matrix (or fibro-vascular callus)
* a significant increase of echo-type IV, indicative for the presence of an amorphous matrix and/or free fluid



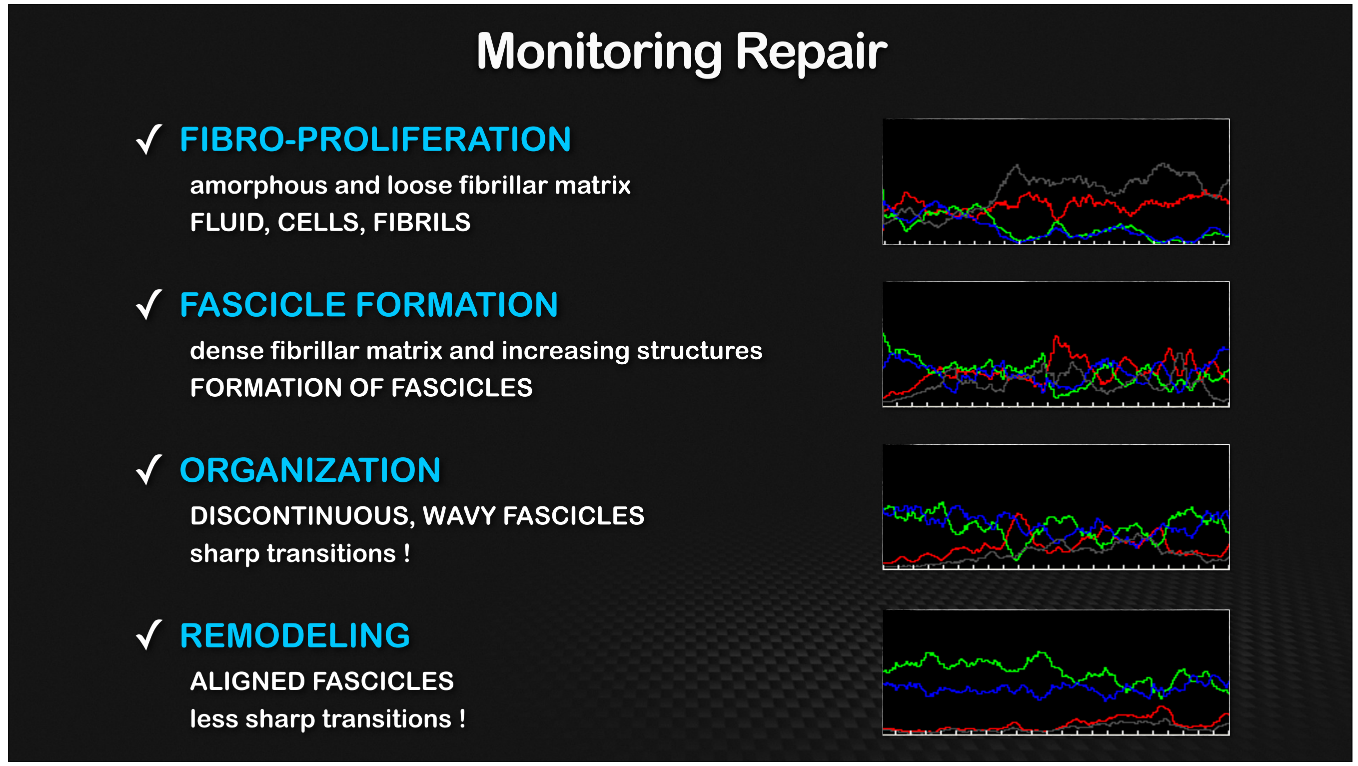
Based on fundamental research, by means of precisely matching UTC processed images with histo-morphology of tissue specimen, a schedule was developed to discriminate stages of tendon integrity.
This schedule can be used for staging of lesions, for quantitative monitoring of repair and for objective evaluation of therapeutic interventions.

Stage I: during disintegration and inflammation there is complete lack of structure, so barely any echo-types I and II. Structure is replaced by haematoma and exudate (echo-type IV, black) and by a fibrillar matrix (echo-type III, red).

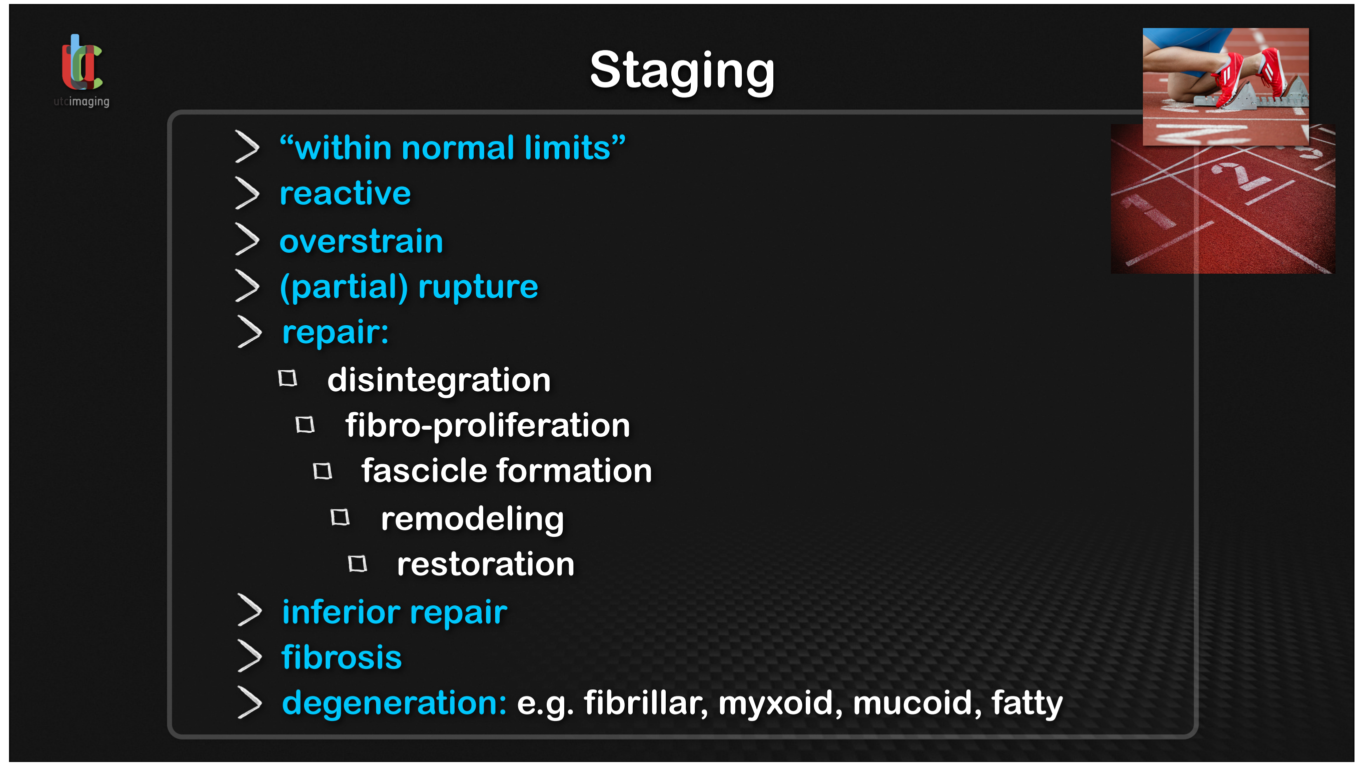
Stage II: during fibrillogenesis, there are still barely any structures, so only low percentages type I and II echoes. There is a significant decrease of type IV echoes (black) and an increase of type III (red), indicative for the formation of a fibrillar matrix. Especially the ratio echo-type III/echo-type IV is an important indicator: an increase of ratio III/IV is indicative for a fibrillar matrix that is getting more dense, an important first step leading towards organization.

Stage III: during organization of fibrils into fascicles, echo-types I (green) and II (blue) do increase, indicative for organization of the fibrillar matrix into fascicles. The relatively high percentage of echo-types II indicates that fascicles are still discontinuous and not properly aligned in lines of stress yet. At the same time, echo-types III (red) and IV (black) decrease sharply.

Stage IV: during the remodeling stage, a decrease of type II echoes (blue) can be observed in favor of an increase of echo-type I. This indicates that discontinuous fascicles that initially were not properly aligned yet are remodeled into intact and aligned fascicles. As such the ratio echo-type I/echo-type II is an important prognostic indicator for the quality of repair: a high I/II ratio indicates good quality of repair while, on the other hand, a low I/II ratio due to persistently high percentages of echo-type II is indicative for inferior quality of repair, leading to fibrotic scar tissue.



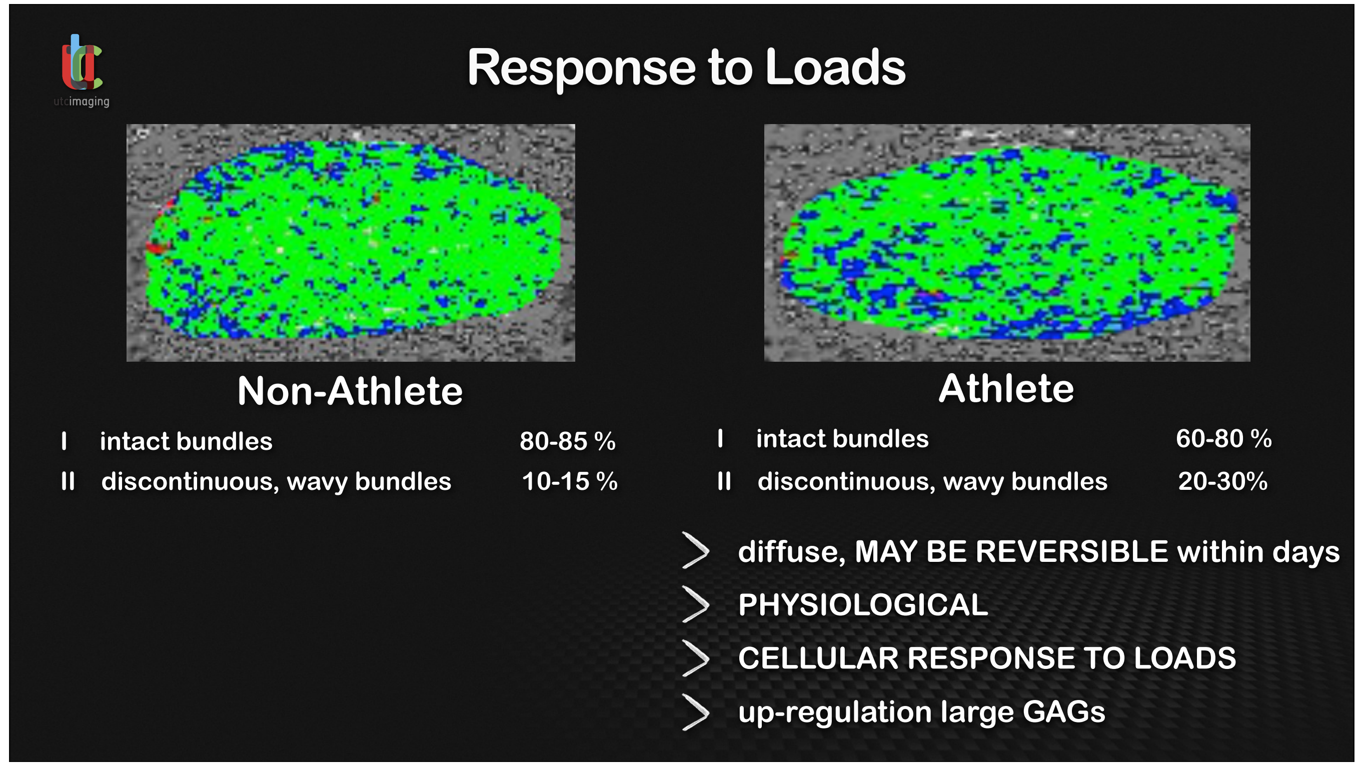
The schedule for staging of lesions can be used for objective monitoring of repair processes.
Going through stages of
FIBRO-PROLIFERATION
FASCICLE FORMATION
ORGANIZATION
and REMODELING
A gradual improvement of tendon integrity can be quantified.
Besides the increase of intact fascicles, also the disappearance of sharp transitions between tissue types, seen as spikes in the graphs, indicate quality of repair.
The stage of integrity appeared to correlate with loading capacity and as such this staging tool can be used for guided rehabilitation.



As mentioned before the management of tendinopathy is frequently hampered by the sneaky onset of matrix degradation (symptoms are only the tip of the iceberg) and by the lack of insight into the stage of the lesion. The early detection of matrix changes is vital for injury-prevention. And for an effective treatment staging of the lesion is crucial.

UTC imaging has developed algorithms to discriminate a variety of stages like:

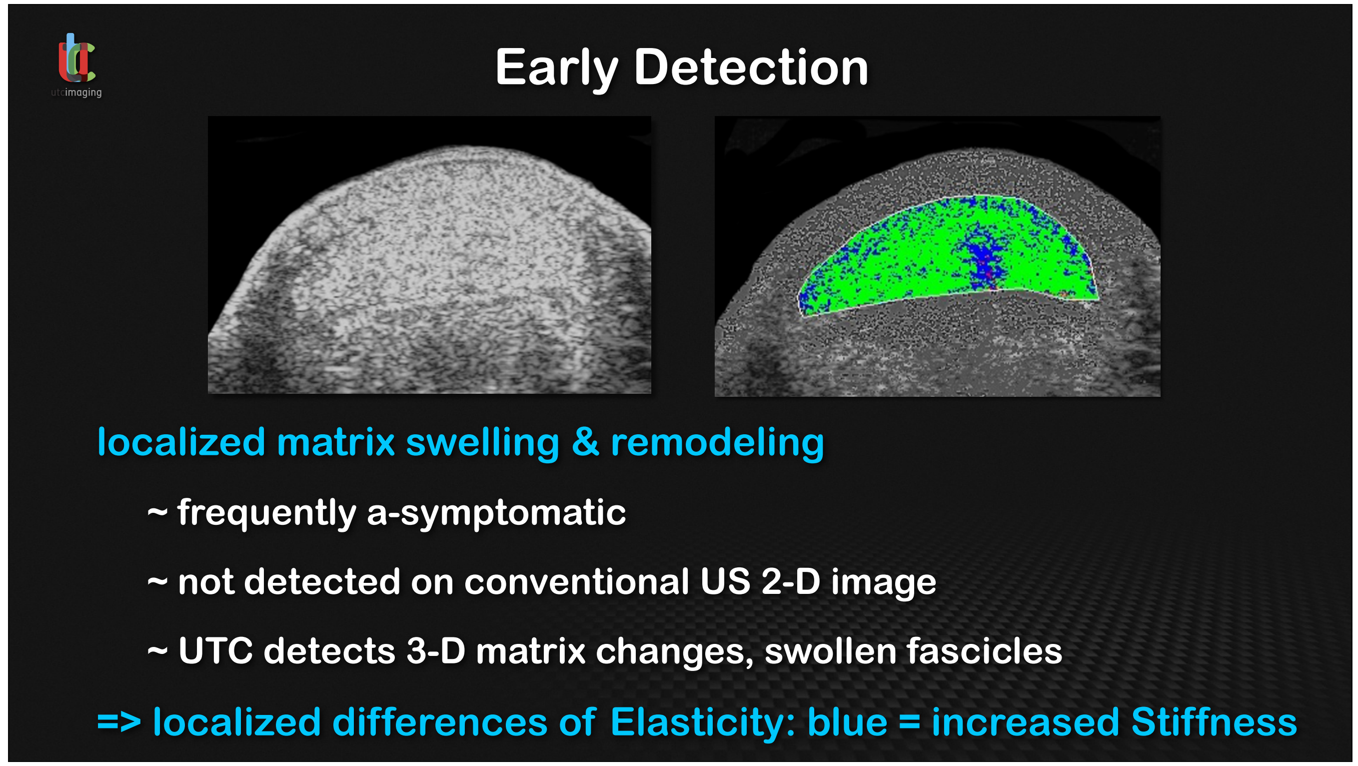
+ normal, or preferably called "within normal limits"
+ reactive
+ overstrain
+ partial or complete rupture
+ stages of repair, such as disintegration, fibro-proliferation, fascicle formation, remodeling, restoration
+ inferior repair
+ degeneration



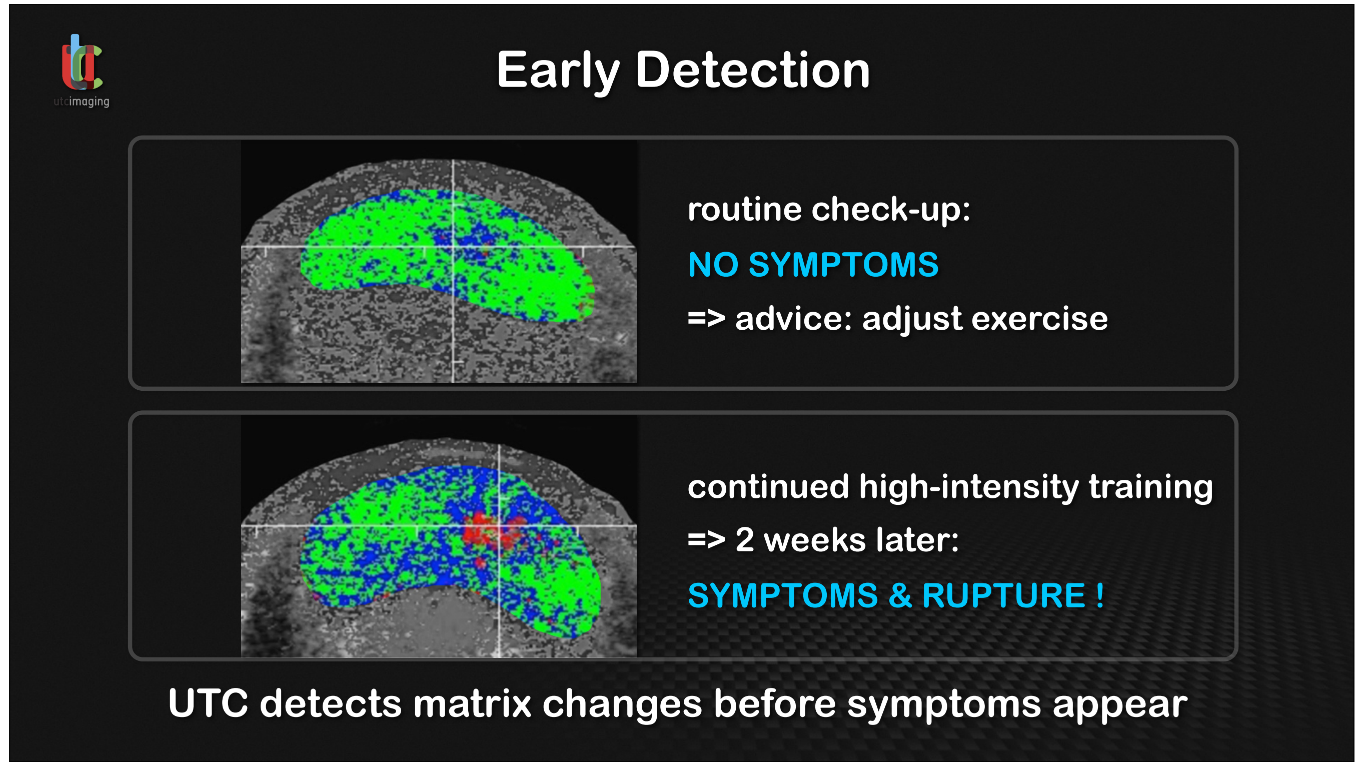
As mentioned before, a normal Achilles tendon in NON-ATHLETIC people, consists of
* **80-85 percent echo-type I, and**
* **10-15 percent echo-type II**

However, in ATHLETIC persons frequently a significant decrease of echo-type I and significant increase of echo-type II can be found. This is not pathological, rather it is indicative for increased bundle swelling due to physiological load-response of the matrix. This may be reversible within days, especially when echo-types II are diffusely-distributed. When echo-types II are more localized it may have more serious consequences, see next slides.

Please notice: barely any type III or IV echoes thus no disintegration and no free fluid. There is an increase of fluid in the inter-fibrillar matrix within the fascicles, but no free fluid in the inter-fascicular septa surrounding the fascicles.



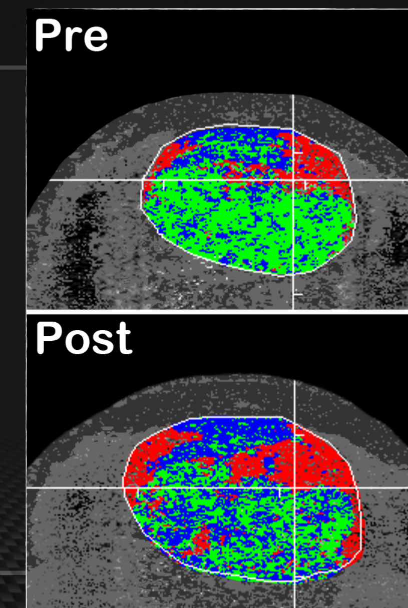
This is a challenging case showing transverse images of an Achilles tendon after heavy exercise.
No clinical symptoms!
No abnormalities on grayscale!
However, the UTC-processed image reveals a localized blue spot which is indicative for swelling and/or remodeling of fascicles. As response to loads there is an increased production of high-molecular glycosaminoglycans, binding increased amounts of fluid within the 3-D fibrillar matrix, leading to increased stiffness of the fascicles.
During fundamental research underlying UTC algorithms biomechanical loading tests were done on isolated tendons. Precise matching of UTC processed images with local strain characteristics (as measured by local stress-strain curves) confirmed that in regions generating echo-type II (blue) the matrix has increased stiffness (increased steepness of stress-strain curve).
These changes may still be reversible, may be within days with appropriate load management.
In contrast to the diffusely-spreaded increase of type II echoes as shown in the previous slide 30, these changes are localized.
Our fundamental research revealed that especially when changes in the tendon matrix are localized, seen as the blue spot, there is local variation in elasticity: normal fascicles (type I echoes, green) have normal physiological elasticity while swollen fascicles (type II echoes, blue) have increased stiffness. Local differences in matrix stiffness may put the tendon at risk.
For injury-prevention in these cases UTC-guided load management can be vital.



UTC appeared to be highly sensitive to detect load effects. As such it can be used for load-management and injury-prevention.
For example, this player showed at regular check-up a localized blue spot in the center of the Achilles tendon. Without any clinical symptoms.
These changes had not been observed on a previous check-up some weeks before. It was recommended to reduce loads but despite this advice, the athlete continued high-intensity training.
And, regretfully for him, he came back 2 weeks later: in pain due to a fully-developed partial rupture, exactly in the blue spot. As mentioned before (slide 31), the blue spot indicates matrix remodeling with swollen fascicles that have, may be temporarily, increased stiffness putting the tendon at risk.
This was one of those cases that clearly show the possibilities to monitor load-effects and to predict and hopefully prevent tendon injury by means of regular UTC check-up's.

Adverse Reactions to Exercise

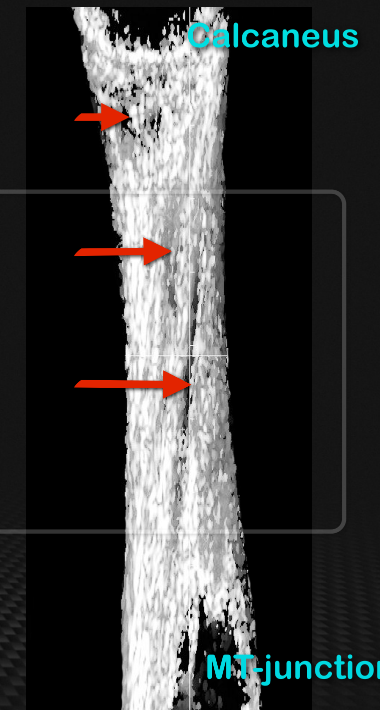
- serious disintegration within 2 weeks after starting eccentric loading
- misdiagnosed dorsal partial ruptures may lead to enlarged ruptures and lengthening of tendon (Alfredson et al. BJSM 2011)



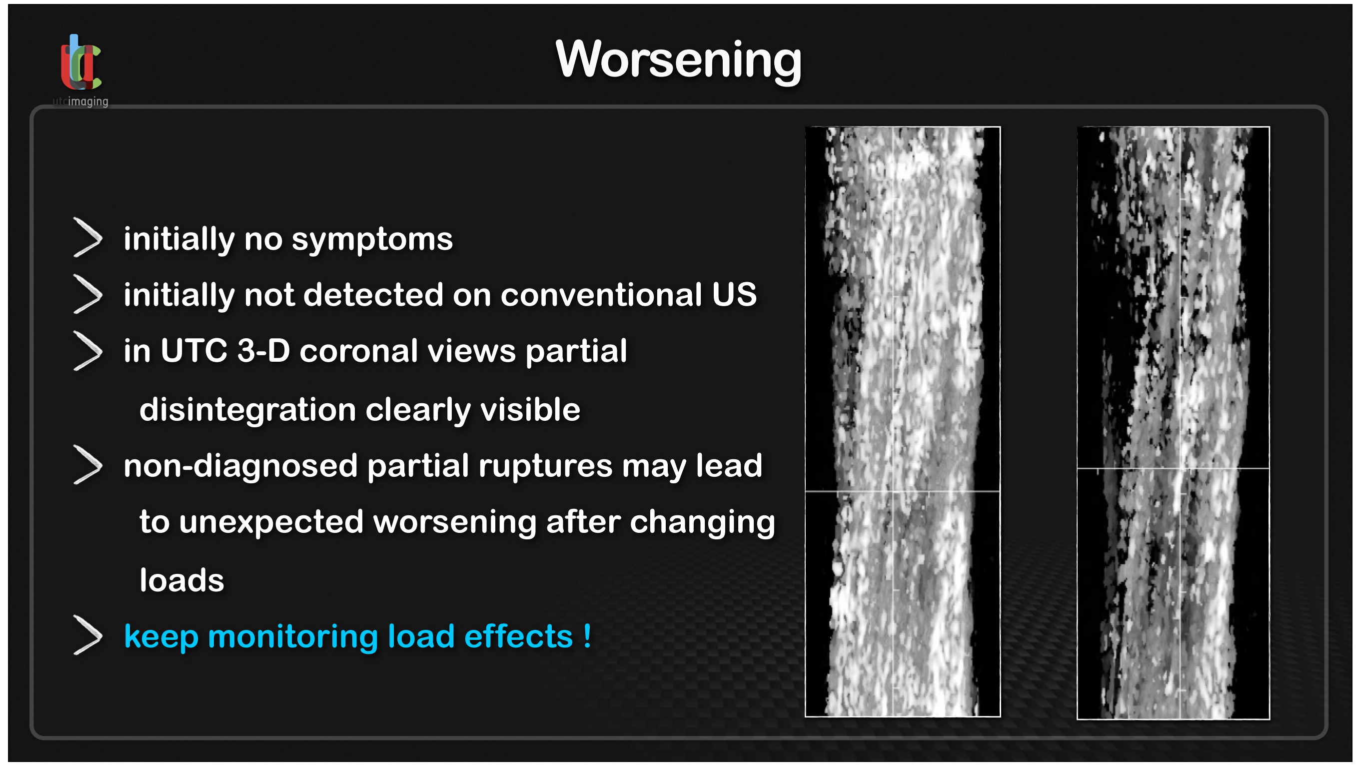
This is another example of the sensitivity of UTC to detect changes in loading protocol.
This case showed a striking disintegration within 2 weeks after the start of eccentric exercise which may occur in cases of dorsal partial ruptures, exposed to the highest eccentric loads, that were not detected before.
Exercise that is not based on proper diagnosis or staging may lead to serious worsening. See next slides 34-37.

Partial Ruptures

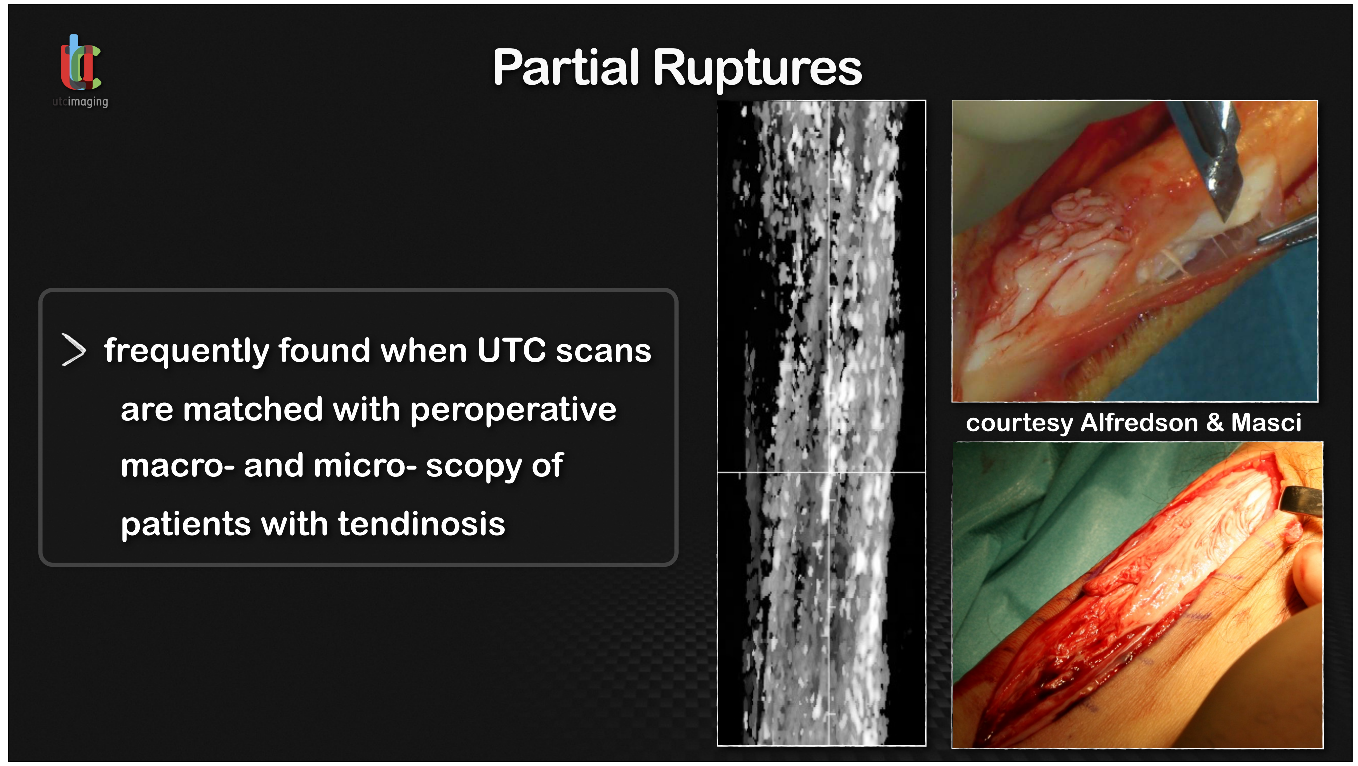
- frequently found in tendinotic tendons, located mostly on the dorsal side of Achilles tendon
- not always detected by US (Kayser et al. BJSM 2005)



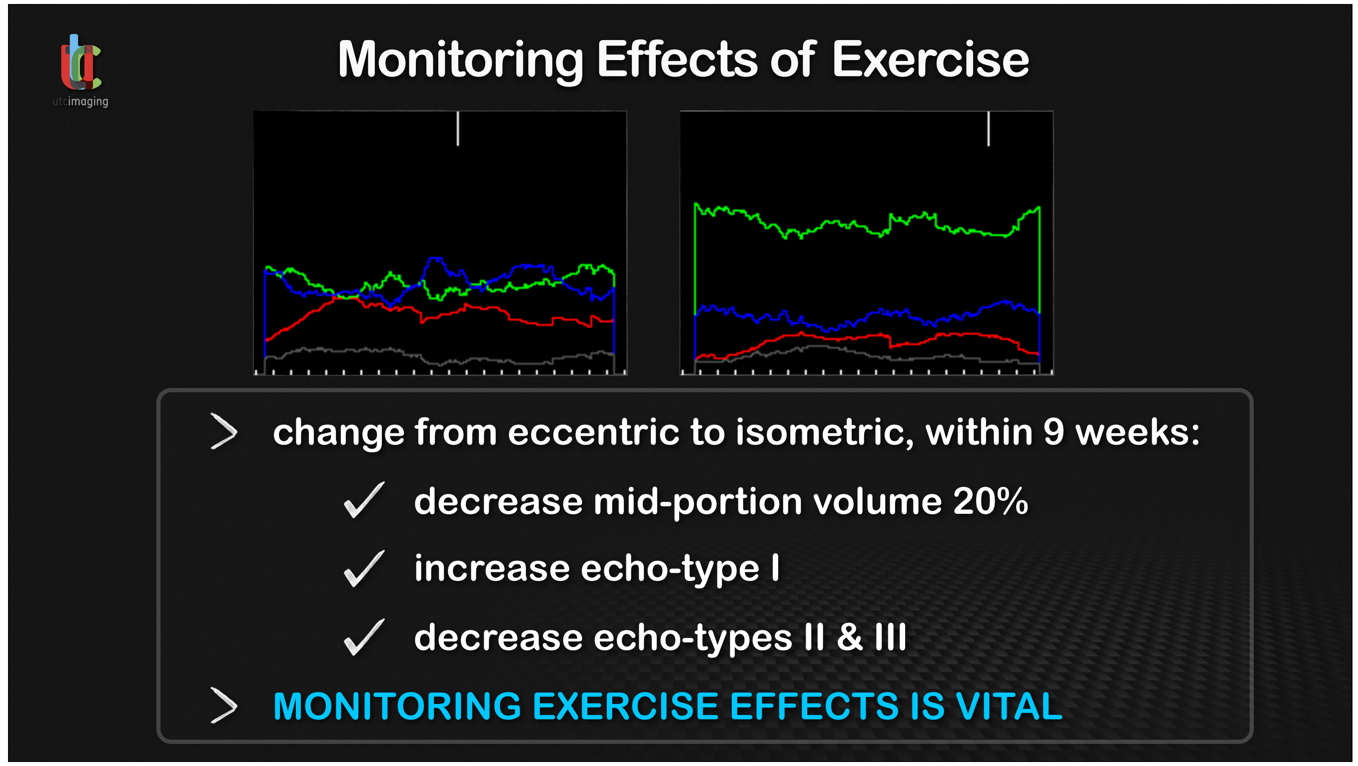
Partial ruptures can be observed during surgery (see slide 36), mainly in the dorsal side which is exposed to the highest eccentric loads.
However, these tiny ruptures are not always detected by conventional ultrasound.
In contrast, UTC imaging clearly visualizes already small-scale disintegrations, especially in the 3-D coronal view, like:
* ruptures in the insertion on the calcaneus
* dorsal partial ruptures
Please notice also the rotation of the fascicles, a normal phenomenon in the mid-portion.



These 3-D coronal images of the same Achilles tendon are made 3 weeks apart.
To the left the scan prior to increasing loads, showing already remarkable disintegration in the dorsal side of the Achilles tendon
To the right the scan only 3 weeks later, showing a substantial worsening with extensive loss of structural integrity.
Therefore, both a thorough search for partial ruptures prior to changing loads and subsequently monitoring load effects is highly recommended !



Partial ruptures, clearly visible on pre-surgery UTC scans, especially in the 3-D coronal view, are confirmed during surgery.



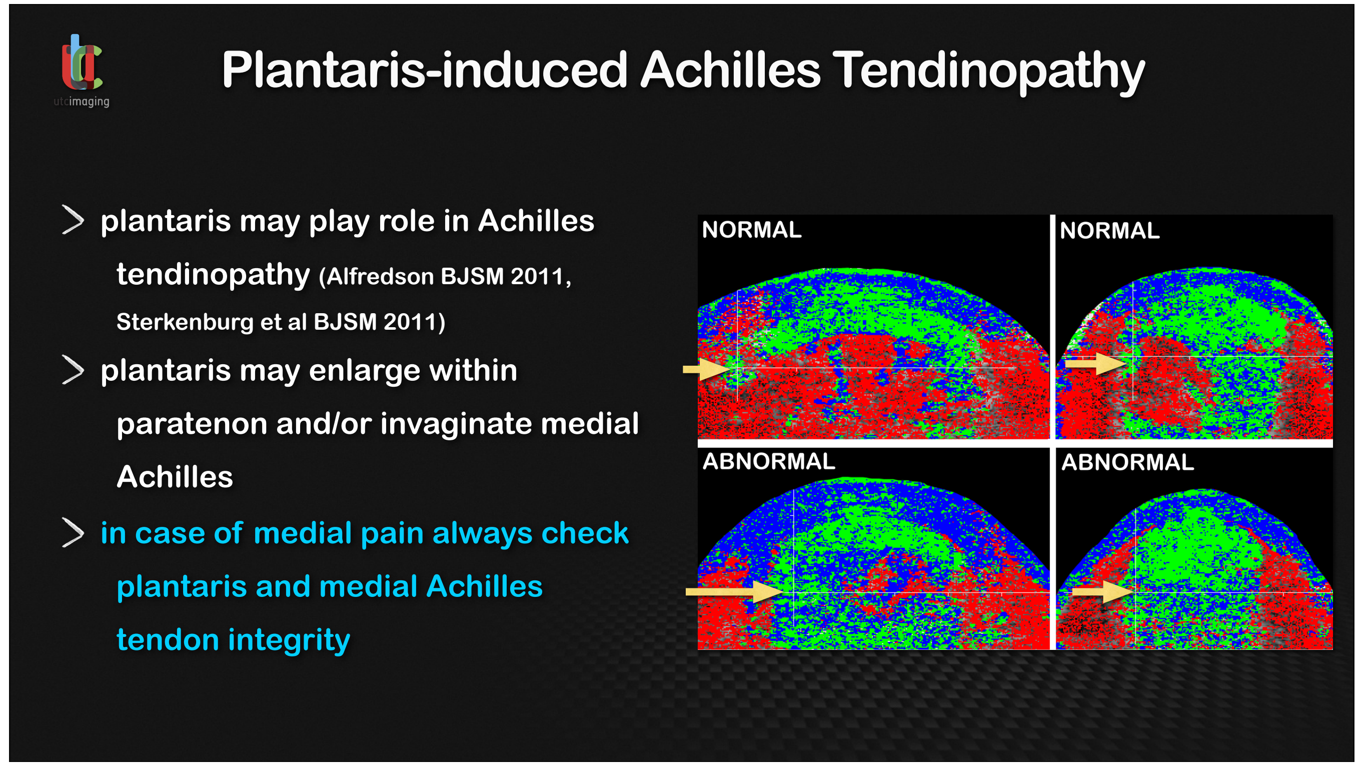
If a substantial worsening is diagnosed in time, changing the loading protocol can be monitored.
Graphs represent tendon integrity at 2 time-points, 9 weeks in between.
The graph on the right side, collected at 9 weeks after change of exercise clearly shows that:

+ mid-portion volume has decreased 20 %
+ tendon integrity improved significantly.

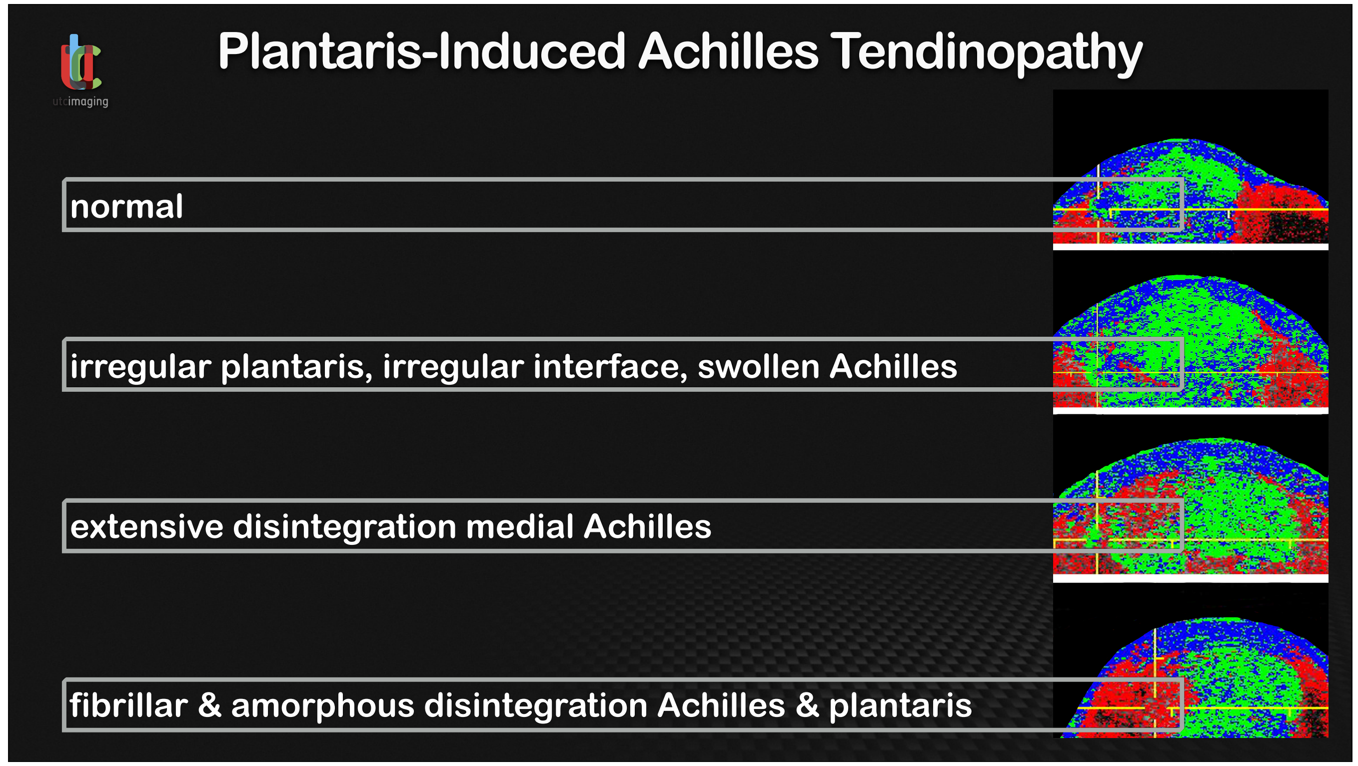
Please do not misunderstand: I do not say that eccentric is bad and isometric is good!
I only say that:

1. effects of exercise or change of load management should be monitored
2. UTC is both reproducible and sensitive enough to monitor improvement of integrity already within days or weeks.

As such it can be used for guided rehabilitation!



There is growing evidence that the plantaris tendon plays a role in development of Achilles tendinopathy, especially in case of medial complaints.
The 2 images on top show a normal plantaris, close to but separated from the medial side of the Achilles tendon.
Below an abnormal plantaris that is enlarged and disintegrated. Furthermore, the anterior paratenon that envelops Achilles and plantaris is clearly abnormal.
Please notice that overall the Achilles tendon itself doesn't look that poor (yet).



In the normal situation (Stage I) a slender and clearly circumscribed plantaris tendon can be found. The interface between Achilles and plantaris is mainly blue (type II), indicative for fibrous tissue.

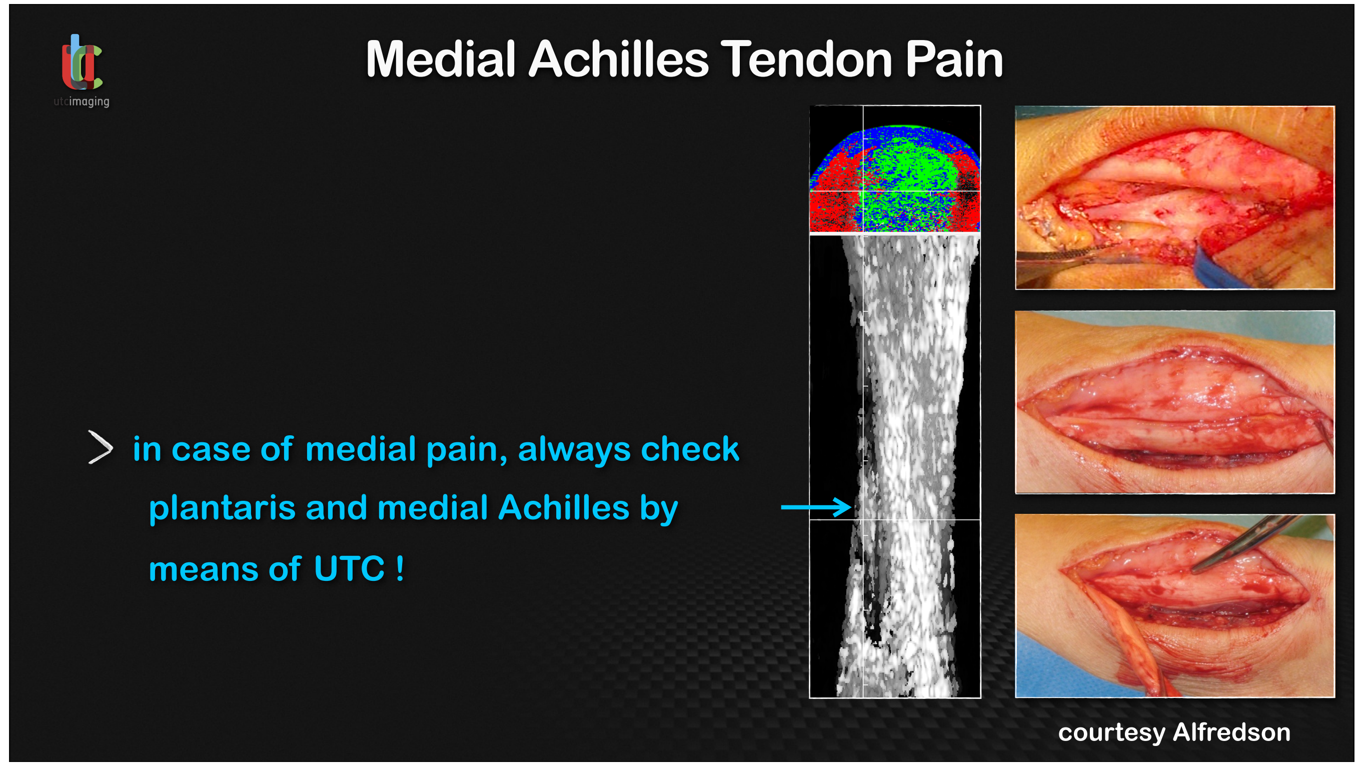
In "plantaris" cases several features can be discriminated:

Stage II is frequently seen in young active athletes with medial pain. In most cases the grayscale US shows an Achilles tendon that is somewhat plumb but without significant changes of echogenicity. On UTC the Achilles tendon is swollen (plumb and with increased AP thickness) but there is no loss of structure. Also the plantaris is enlarged with irregular outline. Most striking observation is the red/black interface, thus fibrillar and amorphous tissue, that "separates" Achilles and plantaris tendon; there is no sharp interface anymore. During surgery this interface appears to be a layer of fat tissue, highly vascularized and innervated (Hakan Alfredson, Christoph Spang). See next slide 40.

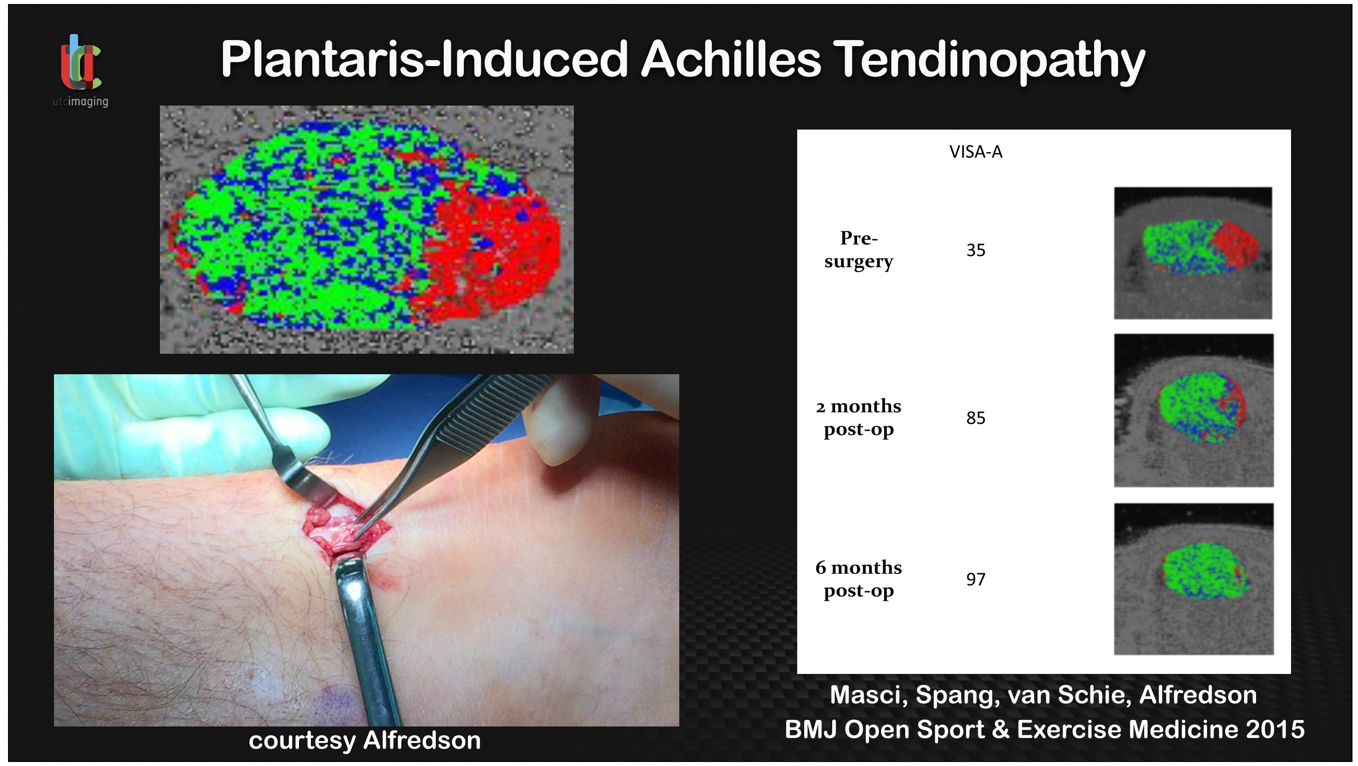
Stage III still a "tendinous" plantaris can be found but in contrast to stage II now there is an extensive disintegration, mainly fibrillar and amorphous, of the medial Achilles tendon.

Stage IV no isolated plantaris can be observed. This doesn't necessarily mean that there is no plantaris anymore, rather that the plantaris has lost the purely tendinous matrix, becoming more and more fibrillar and/or amorphous, and/or merged with the disintegrated Achilles tendon.

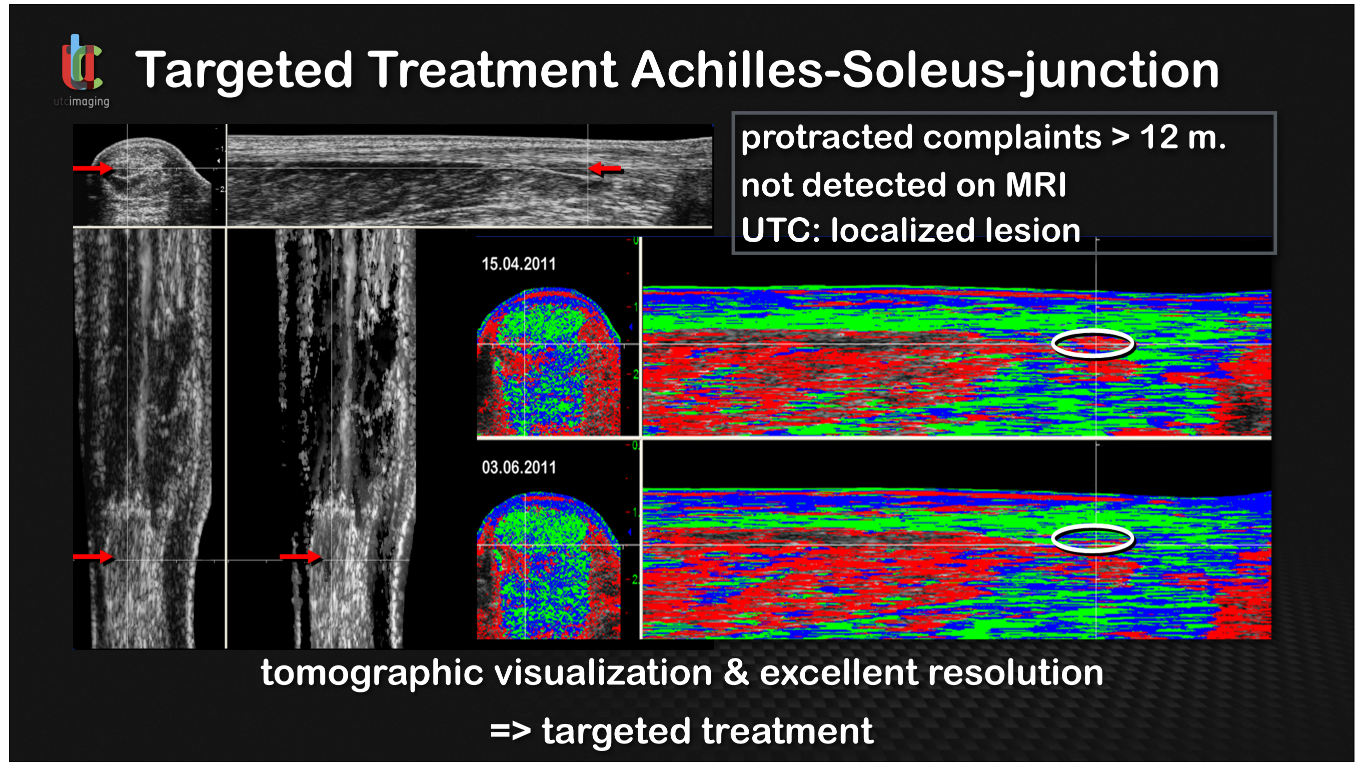
In stages III and IV the medial border of the Achilles tendon has disappeared and normal tendon tissue is replaced by a more or less dense fibrillar and amorphous matrix. These structural changes gradually spread over the entire cross section and frequently fibrillar (red) is surrounded by remodeling or fibrotic tissue (blue).



This is a patient with medial pain.
On UTC the majority of the Achilles is “normal” but the medial side is obviously abnormal.
The 3-D coronal view clearly visualizes the plantaris and the disintegrated medial Achilles tendon. Especially the medial border of the Achilles tendon has disappeared and normal tendon tissue is replaced by more or less dense fibrillar and amorphous matrix.
During surgery the plantaris and Achilles tendons are separated by fatty tissue, mainly red and black in the transverse image.

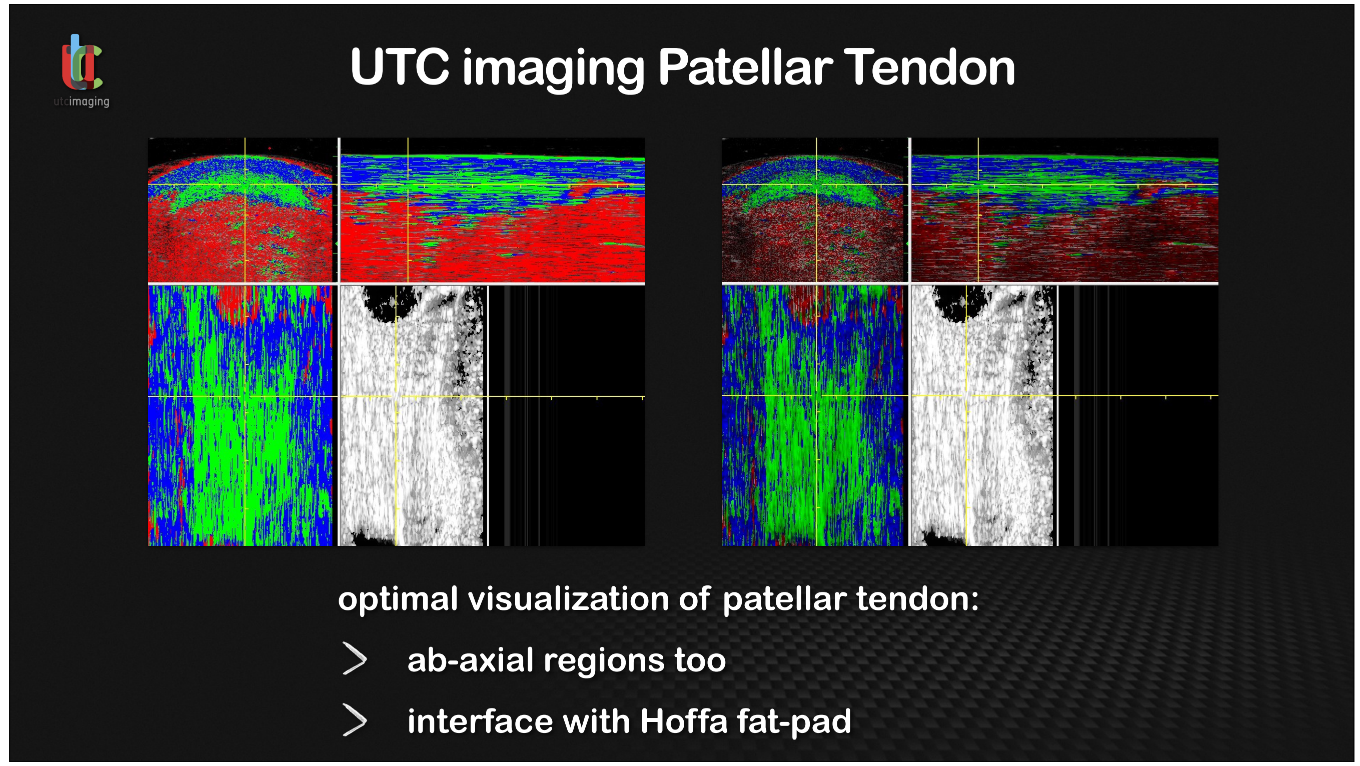


After diagnosis of plantaris-induced Achilles tendinopathy, minimally-invasive surgery (removal of fatty layer, partial removal of plantaris and scraping of antero-medial side of Achilles tendon) may lead to significant improvement. After surgery the repair can be monitored by means of regular UTC imaging. Even in patients with extensive degenerative disintegration of the medial part of the Achilles tendon a significant restoration of tendon structure can be observed within 6 months post-surgery which correlates with improvement on VISA-A.

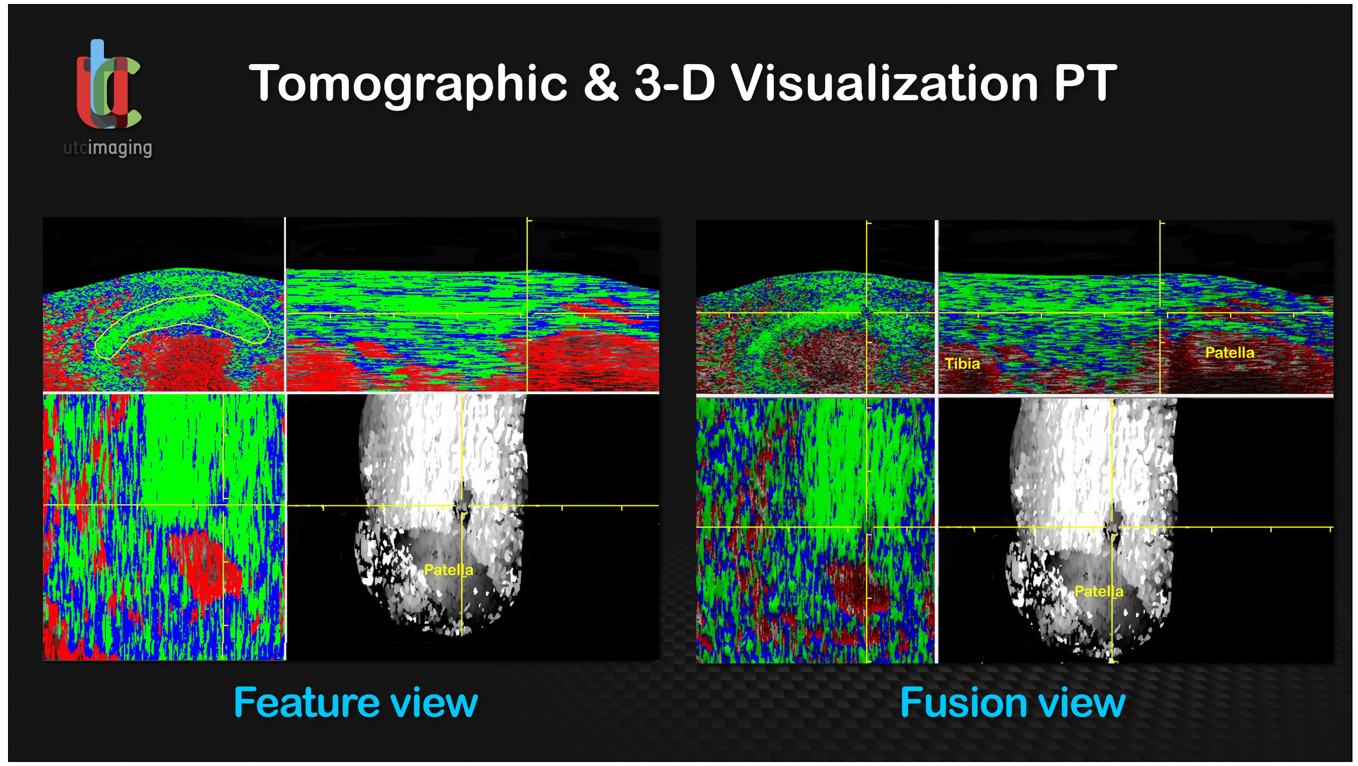


This is a high-level athlete with serious discomfort and loss of function for more than one year.
On MRI scans no relevant changes could be detected.
UTC revealed a small sagittal lesion filled with mainly fibrillar tissue (red), visible in all planes of view, localized where soleus muscle merges with the gastrocnemius (comparison with contra-lateral confirmed these uni-lateral structural abnormalities).
Based on precise localization the lesion was infiltrated on spot twice with 1 ml PRP, 2 weeks apart, and subsequently only once with ESWT (focussed, electro-hydraulic, 600 pulses). From 2 weeks post-treatment light exercise was resumed and at 6 weeks loading capacity was already 40-50%. UTC at 6 weeks post-treatment revealed a substantial improvement of tendon structure: the lesion had filled in with good quality of repair. After another 6 weeks already full loading capacity was accomplished.
This case is no pro or con for PRP and/or ESWT, rather it is exemplary for the excellent resolution of UTC and the benefits of multiple planes of view for targeted on-spot infiltrations.

UTC imaging of Jumpers Knee



Also for scanning the patellar tendon the cylindrical stand-off facilitates optimal visualization of more ab-axial parts of the tendon.
With standardized settings the focal point is laid at deep side of the patellar tendon in order to visualize the interface between patellar tendon and Hoffa fatpad too. See slide 49.



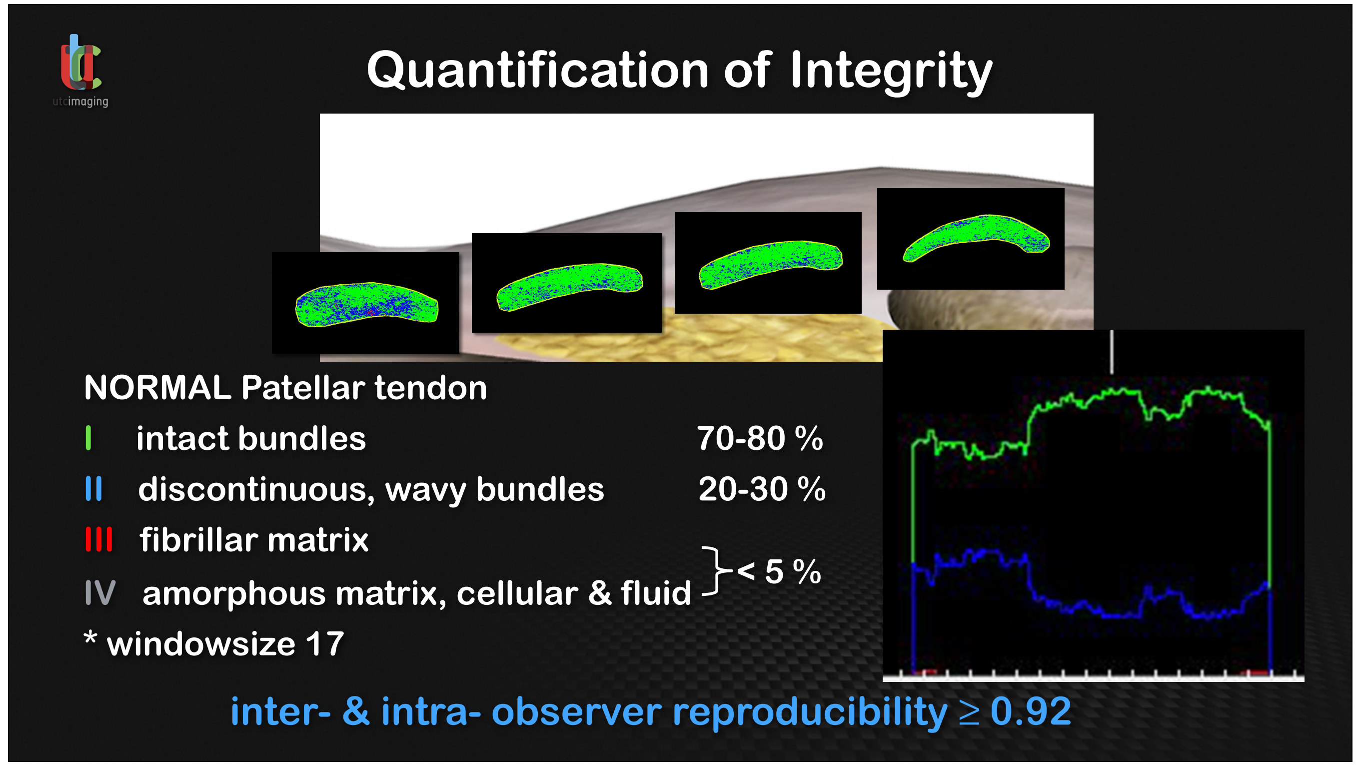
Tissue types are visualized tomographically in

+ feature view
+ fusion view.

The feature view is a plain 2-D image showing distribution of tissue types.

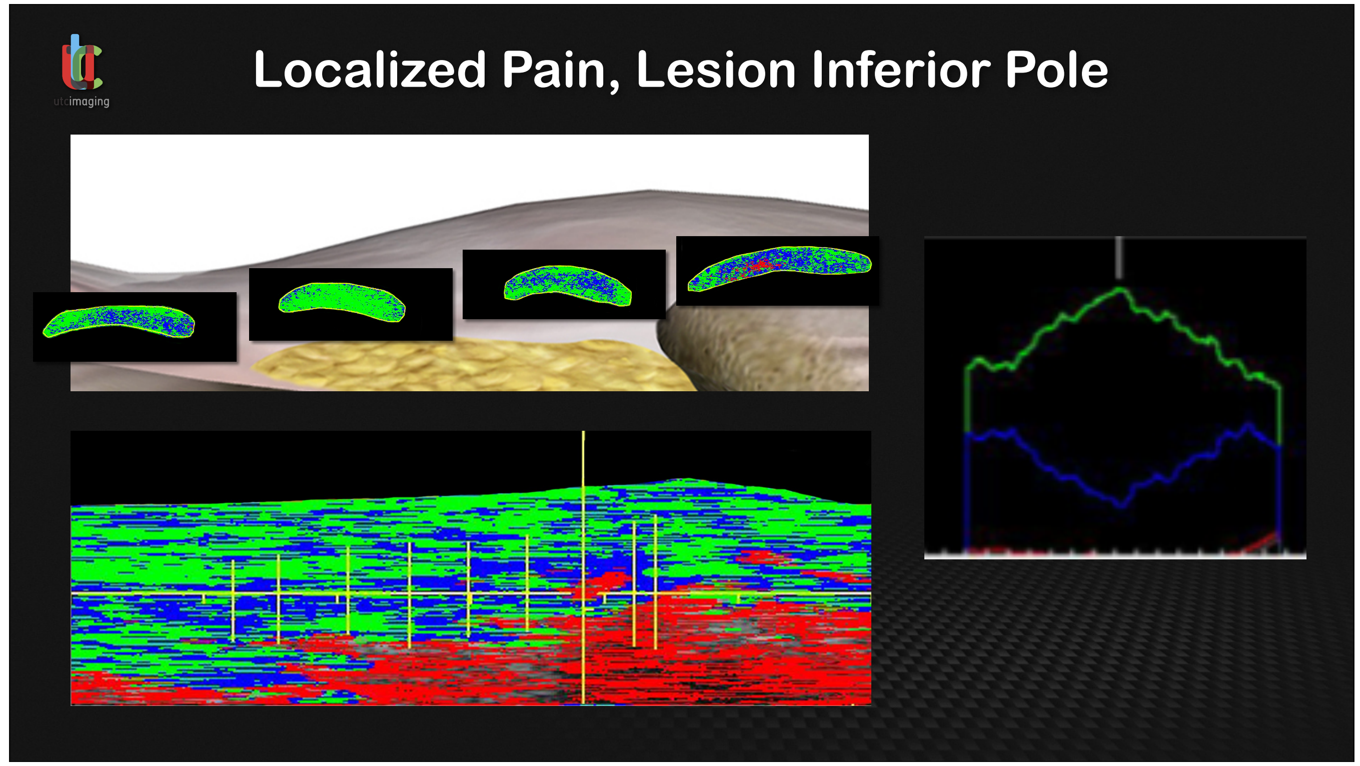
The fusion view consists of multiple, superimposed layers for better visualization of 3-dimensional arrangement of structures. Please compare both coronal images: the fusion view shows more clearly the waviness in fascicles.

These images of the patellar tendon reveal structural irregularity at the inferior patella pole (the patella is the solid interface in the 3-D coronal view).



This is an example of a normal patellar tendon, consisting of
* 70 till 80 percent echo-type I, and
* 20 till 30 percent type II
Please notice: barely any type III or IV echoes.

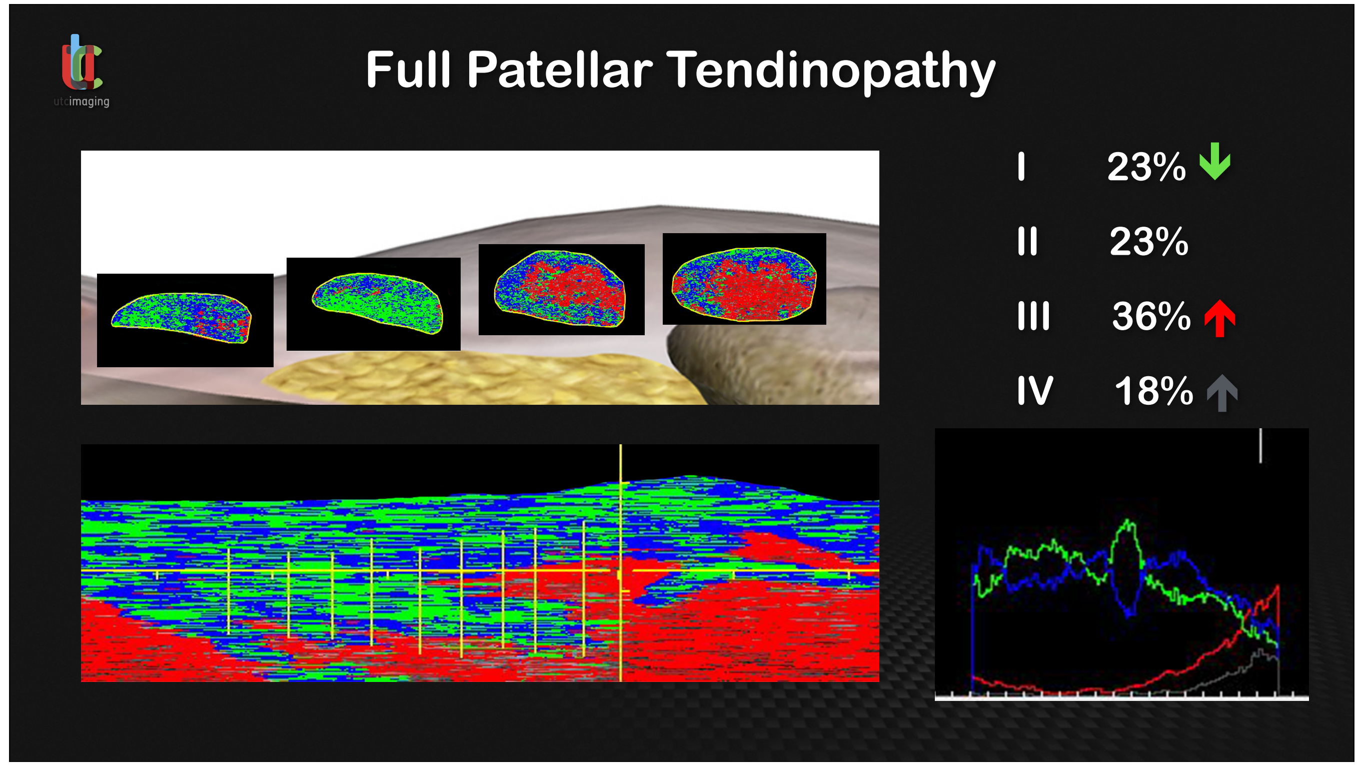
Striking difference with normal Achilles tendons is that normal patellar tendons generate more echo-type II and less echo-type I. This is a physiological phenomenon indicating that fascicles in the patellar tendon are shorter and more wavy.



This is an example of a patient suffering pain at the inferior knee cap due to a localized lesion, not only at the inferior patella pole but also superficially in tissue overlying the knee cap. The lesion is filled mainly with fibrillar tissue (echo-type III, red).

Overall the tendon integrity is fine.

The moderate increase of blue type II echoes at bony insertions (patella and tibia) is physiological being the result of increasing waviness of fascicles towards insertions (the same can be observed in the insertion of the Achilles tendon on the Calcaneus, see slide 23).



This is extensive tendinopathy, with substantial structural disintegration: dramatic decrease of echo-type I, replaced by echo-type III (fibrillar matrix) and echo-type IV (amorphous matrix).

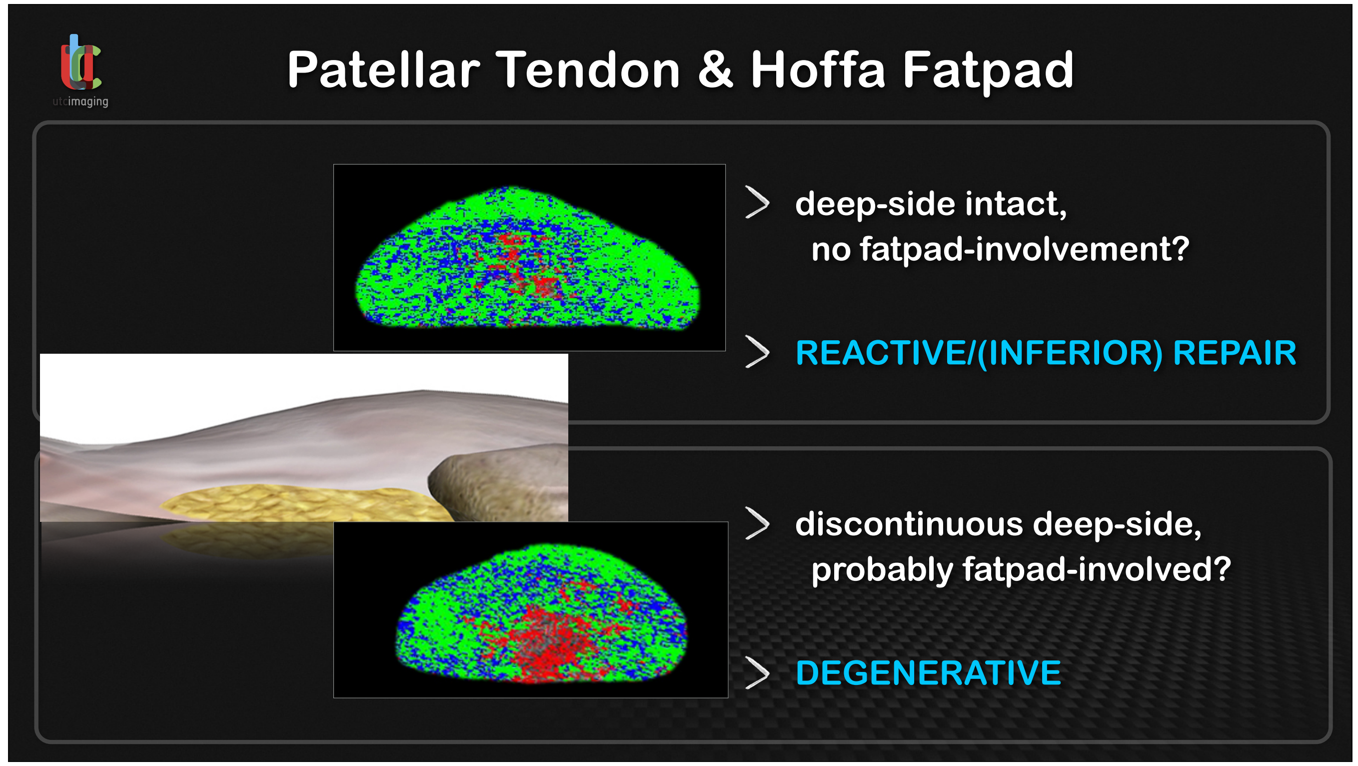
Although pathological changes are most extensive in the most proximal 1.5 cm, to the right, these transverse images collected at several positions along the tendon reveal that the pathology actually spreads over the entire length.

Proximally there is an extensive defect, filled with mainly fibrillar and amorphous tissue, surrounded by remodeling, disorganized and/or fibrotic tissue (echo-type II, blue).

Please notice that the deep side of this lesion is discontinuous (“open towards Hoffa’s fatpad", see slide 49)

Also in the mid-portion, mainly in the anterior region, and in the distal insertion on the tibia remarkable structural disintegration can be observed. Here the presence of significantly increased echo-type II (blue) mixed with some type III echoes (red) is indicative for fibrotic and chronic inferior repair tissue.

As such the graph is characteristic for long-lasting pathology, in most cases leading to intermittent flare-ups.

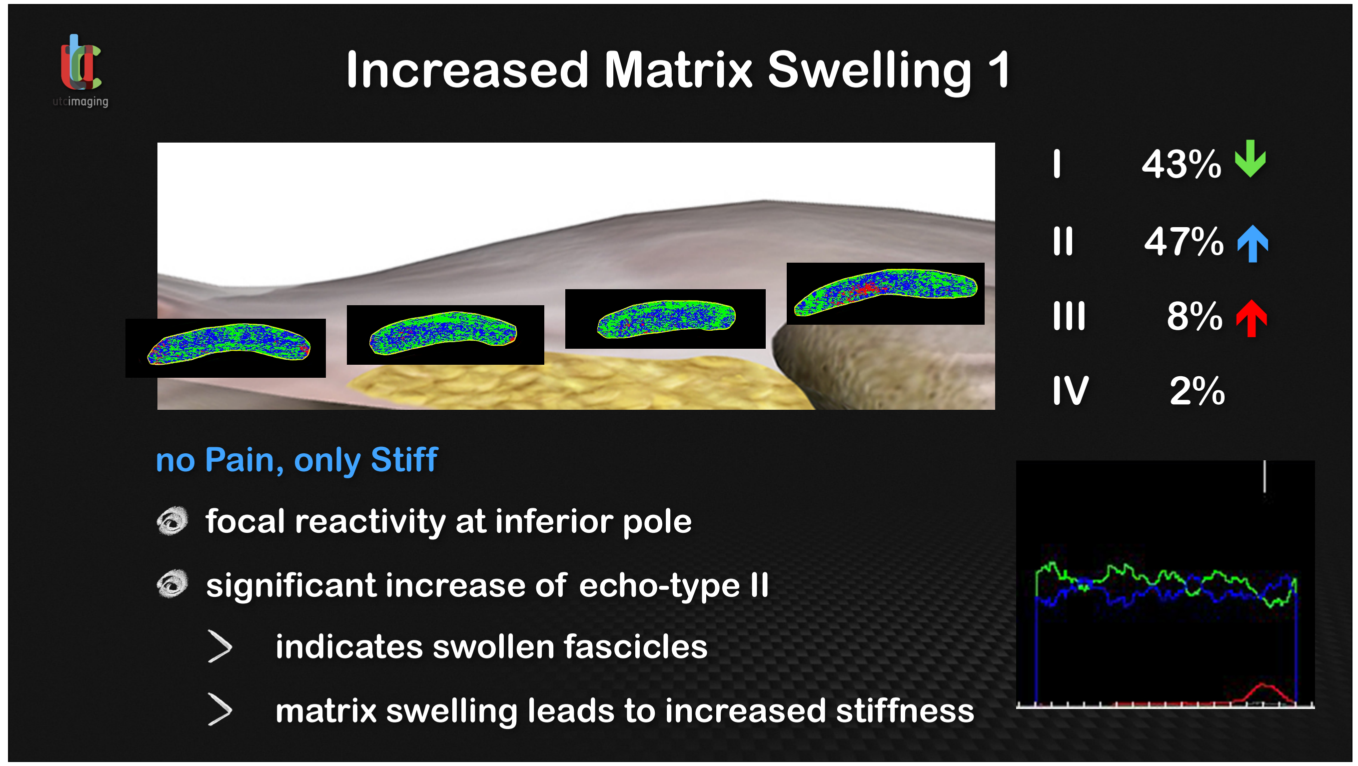


Patellar tendinopathy may have different manifestations on UTC imaging, based on distinctive features like localization of the lesion and the main echo-types.
Localization of the lesion at the inferior patella pole can be a. mainly in the center or b. mainly on the deep side ("open" to Hoffa's fatpad).
Also the tissue types present in the lesion may vary: either 1. a mixture of mainly echo-types II and III or 2. a mixture of mainly echo-types III and IV.

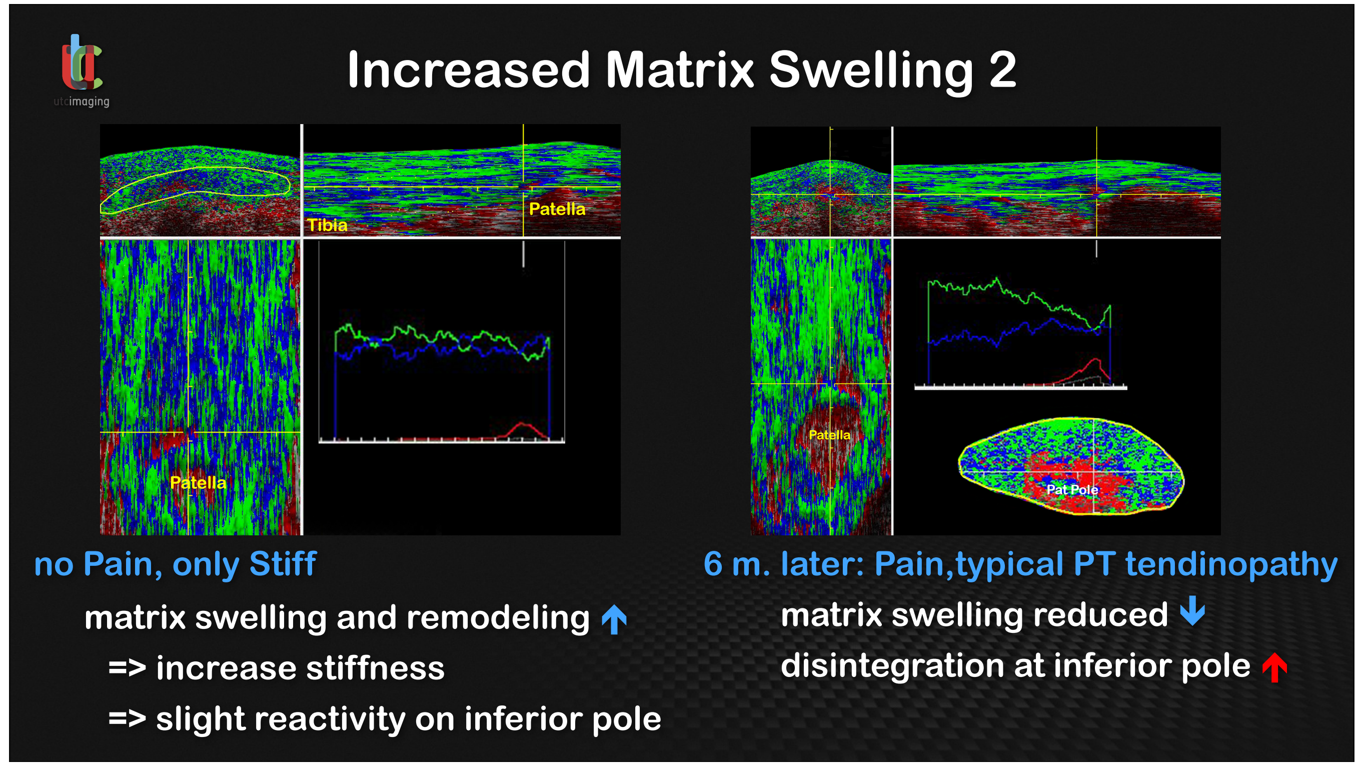
Frequently CENTRAL lesions contain mainly echo-type III (red, generated by fibrillar matrix) in the center, intermingled with and surrounded by echo-type II (blue, generated by remodeling or disorganized and fibrotic fascicles). This combination of echo-types is characteristic for REACTIVE or (INFERIOR) REPAIR stages.

In contrast, lesions that are "OPEN TO FATPAD" frequently contain mainly echo-types III (red, generated by fibrillar matrix) and IV (black, generated by an amorphous matrix). This combination of echo-types is characteristic for DEGENERATIVE stage. The ratio fibrillar/amorphous is an objective measure for the density of the matrix: the lower the ratio, the more amorphous, the more degenerative tendency.

As such the discrimination of lesion type, based on UTC imaging features, might provide important information for selection of appropriate therapy (load management or surgical intervention) and for prognosis. Although this hypothesis is based on observations in an extensive athletic population, it still needs solid scientific proof.



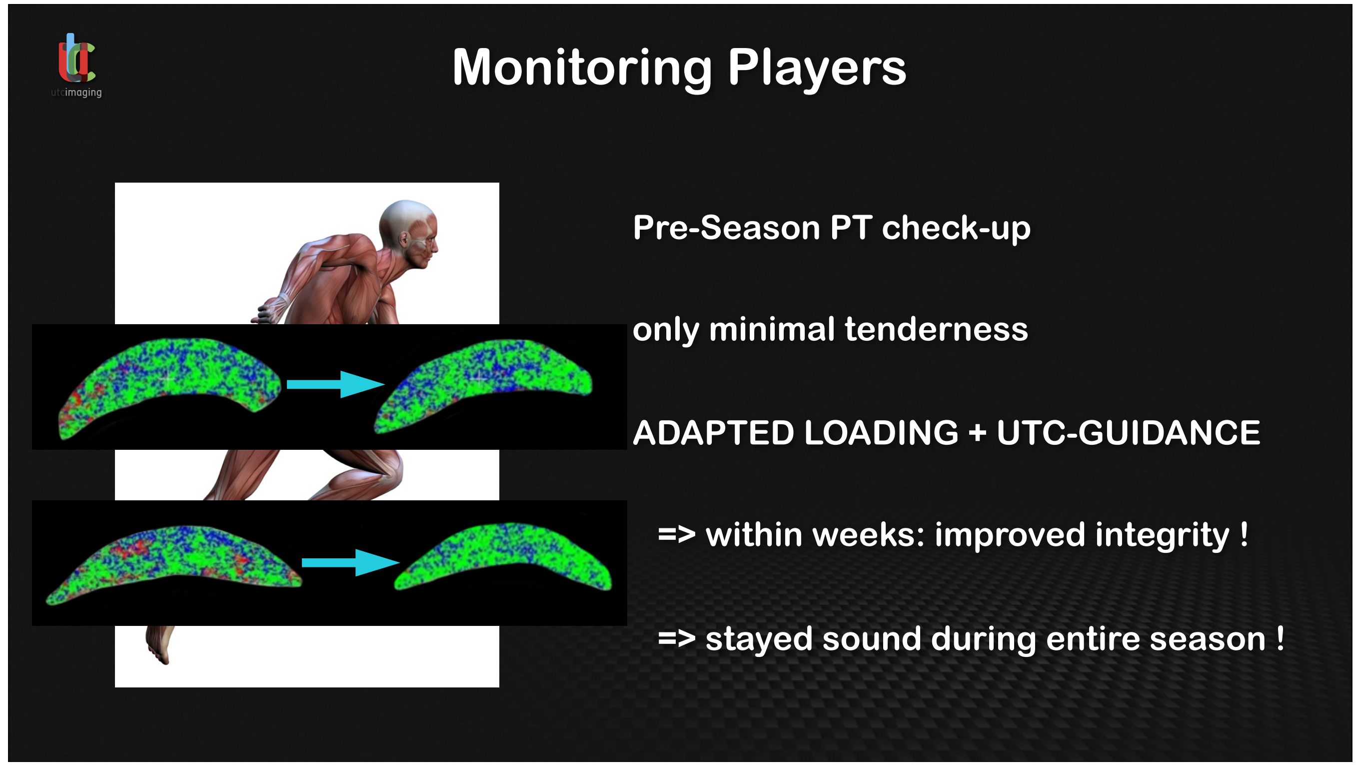
This case is a challenging one: the athlete didn't suffer any pain, the only complaint was that the patellar tendon felt "somewhat stiff".
On UTC imaging there is only mild fibrillar disintegration (red), proximally at the inferior patella pole.
Striking observation is the significant increase of echo-type II (blue), diffusely distributed through-out the tendon.
Echo-type II is indicative for swollen and remodeling fascicles. The fascicles get swollen as a consequence of increased production of large, high-molecular glycosaminoglycans binding fluid inside the fibrillar matrix (see slide 31, 32).
The increased stiffness most probably leads to the mild reactivity in the insertion of the patella tendon at the inferior pole.
Load management and monitoring was advised. See slide 51, next, for follow-up.



But, the athlete didn't want to hear about the advice for load management and monitoring.
Only 6 months later he came back: pain with an extensive patellar tendinopathy.
Now there is serious and extensive disintegration at the inferior pole.
Only good thing is that the matrix swelling further distally diminished (less echo-type II).
This case shows clearly that UTC is sensitive to detect small scale matrix changes already before clinical symptoms become manifest. Even when still small scale, these matrix changes lead to changing biomechanical properties which ultimately may result in serious worsening of tendon integrity and functional capacity. See slides 31, 32 about fundamental research that revealed that swollen fascicles (echo-type II) have increased stiffness.
Please notice the coronal fusion views, bottom left:

+ at first time-point (left) this coronal view clearly visualizes many swollen and wavy fascicles (seen as blue clots) in between normal fascicles (green)
+ at 6 months later (right) the fascicular arrangement has normalized (less blue, more green) with exception of the extensive disintegration filled with mainly fibrillar (red) and even some amorphous (black) matrix at the inferior patella pole.

It is concluded that swollen fascicles, resulting in increased stiffness, ultimately may lead to structural disintegration that may be prevented by early detection and subsequently by load management under UTC-guidance.



Monitoring tendons is “connecting the dots”, only feasible with a reliable tool that allows quantification of integrity. As such UTC imaging is frequently used for monitoring load effects, especially for regular check-ups, not only in-season but also pre-season. See also slides 30-33.

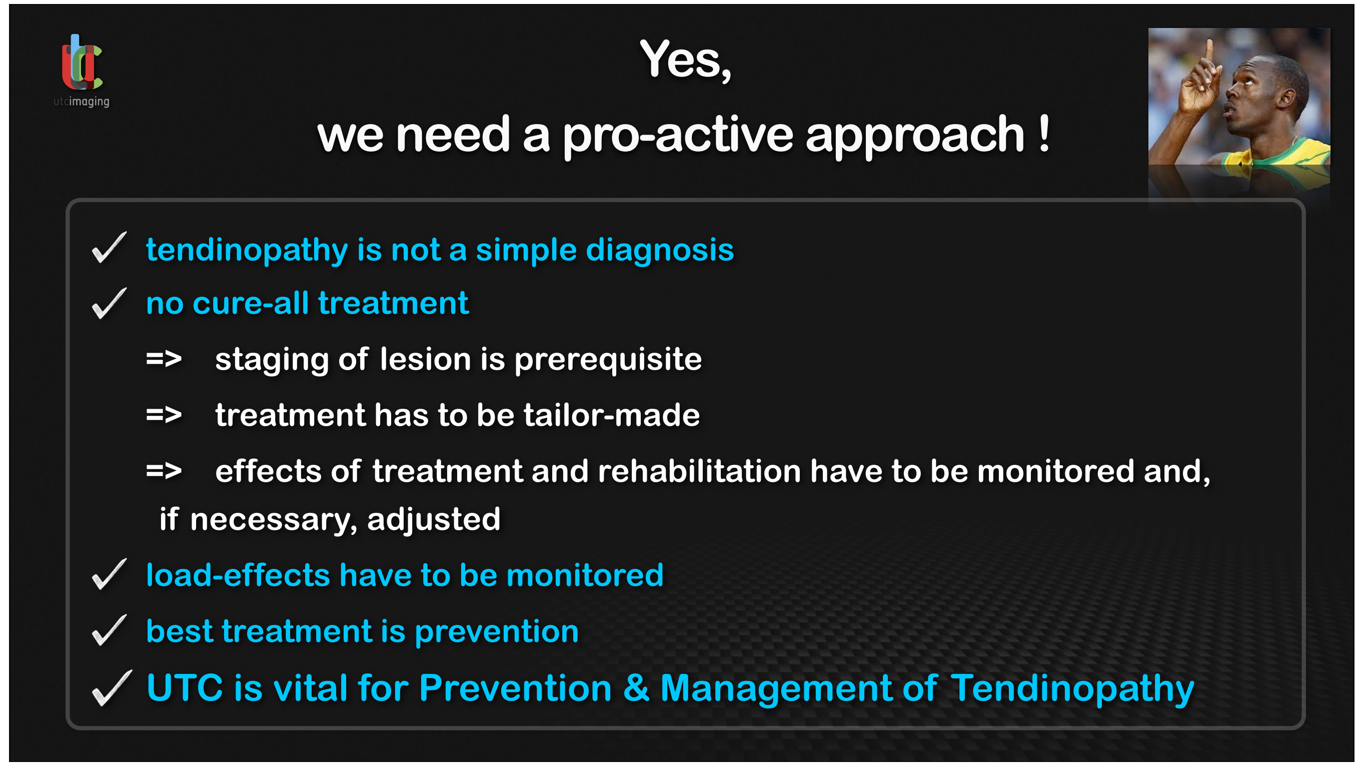
This is an example of moderate, but relevant, changes in the patellar tendon (transverse images to the left), observed during pre-season training.

Despite the fact that there were only minor symptoms, it was decided to change loading under UTC guidance.

Already within a few weeks a significant improvement of integrity was observed (transverse images to the right) and the player returned to play, staying sound for the entire season.

This shows that UTC is sensitive to detect already small scale changes, even without clinical symptoms. UTC can be used for regular check-ups, both pre- and in- season.

As such UTC can be used for injury-prevention, for monitoring load-effects and for guided rehabilitation.



In conclusion:

+ tendinopathy is not a simple diagnosis and there is no cure-all treatment
+ treatment need to be tailor-made, based on precise staging of the injury
+ restoration of full function requires guided rehabilitation
+ and most important, the best treatment is injury-prevention.

To be successful, you need a pro-active approach!
As such, UTC imaging can play a vital role for prevention and management of tendinopathy.

Thank you for your attention!