ViTAL

A Toshiba Medical Systems Group Company

Incorrect Measurements - Z-axis (Transverse/Axial) Rotation Hazard Review Report

ViTAL Lifecycle Document

Document Control History

Rev	Author	Description of Change	Change Request #
A	Jeff Habermaier	Initial Release	DCR-5983

Table of contents

Scope

Potential Hazard

This form documents the evaluation and appropriate action for the incorrect length, area, volume, and angle measurements following the investigation related to defect VIT-6800.

Products Affected

This Hazard Review Report evaluates the potential hazard for the following products:

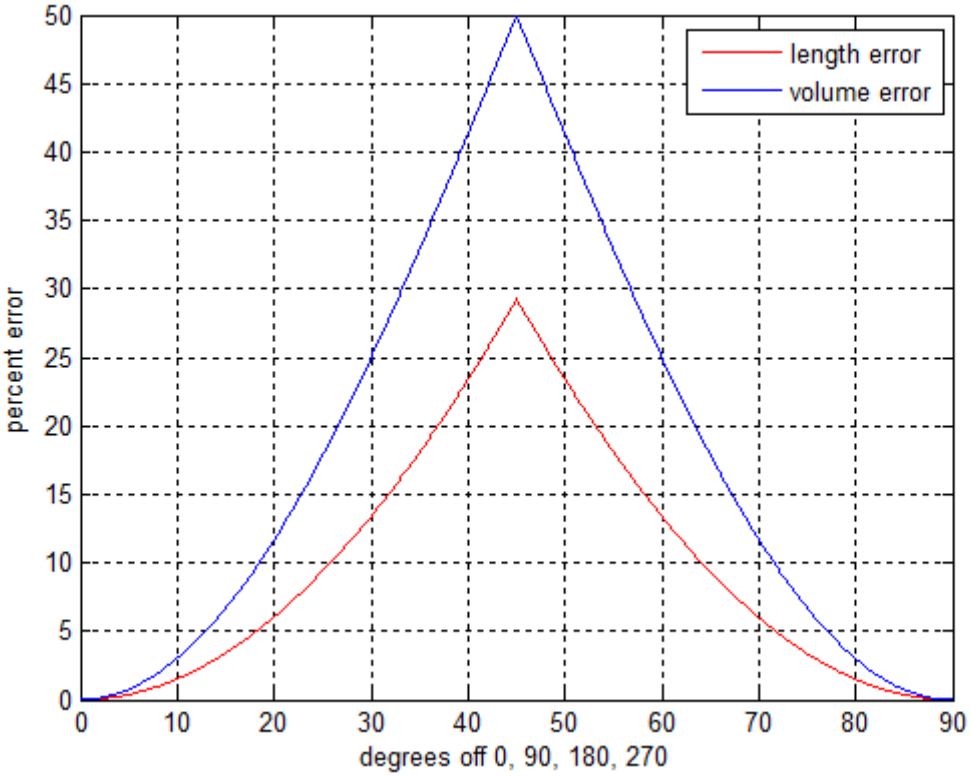
Product Name and Version	Notes
Vitrea, Vitrea fX, VitreaCore	All versions of software except 6.1 SU06, 6.2.3, 6.3, 6.3.1, 6.3.3 (and newer), and 6.4 (and newer).

Issue Summary

An issue was discovered by internal engineering personnel in which, for a dataset with specific characteristics, our software will compute incorrect length, area, volume, and angle measurements. A search of our complaint database found no complaints about this issue and no persons associated with the review of this issue were aware of any customers or other field users identifying a defect related to this issue.

The issue occurs for scans that are acquired axially (z-plane) and are rotated in-plane by a non-90 degree number, while no rotation in the sagittal (x-plane) or coronal (y-plane) planes is performed on the image. For these scans, the images will shrink. The severity of the shrinking is dependent on how severely the images are rotated. The maximum error is a 45 degree rotation which results in a length measurement being under-reported by 29% and a volume measurement being under-reported by 50%.

The graph below illustrates the margin of error in relation to the degrees of rotation.



Dataset Statistical Analysis:

To obtain data to get a better understanding of the probability of occurrence of harm resulting from the error, we reviewed customer data to determine the frequency of scans performed in the manner that causes the error and the magnitude of the resulting errors that appear in field use. The first site we reviewed was Mallinckrodt Institute of Radiology (MIR). This site provided many advantages for analysis, including the following:

- Scan data flow for this facility has all MR and CT scans routed to VIMS, even if there was never any intent to view the scan data in Vitrea, which provides a good

view of possible MR and CT scans that may trigger the issue;

- MIR is a large facility and performs a very wide variety of patient care, resulting in a very diverse set of scans;
- MIR has a very large VIMS storage, holding 5TB of data; giving access to a large amount of scans; and
- Due to research on a similar issue, we had previous volumetric data on MIR's VIMS, which could be added to the different datasets reviewed for this issue, to produce an even larger amount of datasets to view.

Results of Dataset Statistical Analysis:

Two separate reviews of MIR's database were performed . These scans were done on 13-JUL-2012 and 31-OCT-2012, noted as Scan 1 and Scan 2 in the table below. The table also includes results from a separate scan of data of Allegiance Health, which is described below.

# of Volumes	Scan 1	Scan 2	Allegiance	Total
Total # of Volumes Scanned	152,346	80,586	5,151	238,083
Total # of Volumes Exhibiting Error	668	693	14	1,375 (0.58%)
More than 15% Length Error (30% volume)	0	0	1	1 (.00042%)
10-15% Length Error (Max 25-30% Volume Error)	0	3	2	5 (0.0021%)
7-10% Length Error (Max 20% Volume Error)	8	0	0	8 (0.00336%)
6-7% Length Error (Max 14% Volume Error)	0	0	1	1 (0.00042%)
5-6% Length Error (Max 12% Volume Error)	9	3	1	13 (0.00546%)
4-5% Length Error (Max 10% Volume Error)	0	1	0	1 (0.00042%)
3-4% Length Error (Max 8% Volume Error)	6	14	1	21 (0.00882%)
2-3% Length Error (Max 6% Volume Error)	61	60	0	121 (0.05082%)

1-2% Length Error (Max 4% Volume Error)	29	25	8	62 (0.02604%)
0-1% Length Error (Max 1% Volume Error)	555	587	0	1,142 (0.4797%)

MIR builds roughly 37k volumes/week in VIMS, so the aggregate of both scans data represents roughly 6-7 weeks of data.

Allegiance Health is a smaller facility than MIR and does not do MR studies with our software.

- The results at Allegiance found 14 volumes (out of 5,151 volumes -- 0.27%) impacted by this issue. These volumes were visually reviewed and all were CT cases (head or neck) from a Toshiba Aquilion scanner where the study was reconstructed at the scanner to correct a tilt in the head.

Volume #	Max Length Error	Max Area Error / Volume Error
1	22.8%	40.4%
2	11.7%	22.0%
3	11.7%	22.0%
4	6.1%	11.8%
5	5.7%	11.0%
6	3.8%	7.4%
7	1.8%	3.6%
8	1.5%	3.1%
9	1.5%	3.0%
10	1.5%	3.0%
11	1.5%	2.9%
12	1.4%	2.8%
13	1.0%	2.0%
14	1.0%	1.9%

Assessment of margin of error with respect to patient impact:

The base ruler and volume tools can be used in any protocol, thus these tools can be used in a variety of areas. We therefore contacted several doctors to discuss the use of Vitrea products in patient care. Our goal was to determine what these datasets, and the resulting errors, could mean in their respective areas.

Abdominal applications

For this area we spoke to Dr. Lin at MIR.

Dr. Lin discussed two main areas where incorrect length and volume measurements may impact patient care.

Liver Transplant:

Dr. Lin indicated that CT studies for Liver Transplant procedures are one of the highest risk procedures that MIR deals with on a regular basis. Based on his experience, Dr. Lin believed >5% error of measurement for reported volume data could impact patient care and management in the context of Liver Transplantation, both for recipients and donors.

Dr. Lin explained that the transplant recipient needs appropriately sized donor tissue. Oversized transplant tissue would increase surgical risks and transplant success. Additionally, the liver donor needs a minimum of 40% of the organ to remain in order to maintain normative function. If the surgical rescission is too much, the donor would be at risk of detrimental outcomes.

According to the data analysis from MIR and Allegiance, in approximately 0.07% of the cases (7 in 10,000 volumes) the volume measurements would differ from the actual volume by 5% or more.

Kidney Transplant:

Dr. Lin also mentioned kidney transplant procedures. If a donor was selected based on incorrect measurements, but the kidney was too small, the potential donated kidney could be rejected, resulting in a delay in treatment for the recipient, while a new donor was found and evaluated. Similar to liver transplantation, a 5% margin of error would be acceptable, but beyond that, a donor's kidneys may be incorrectly selected.

Muscular Skeletal Applications

For this area, we spoke to Dr. Rubin at MIR.

Dr. Rubin indicated that, in orthopedics, they are used to dealing with a 10% margin of error. This is due to the use of X-Ray film, which is still the orthopedic standard for many applications, and X-Ray film can have a built-in error from magnification of 10-15%.

In reviewing the studies at MIR and Allegiance, six series (.0025%) had a length error greater than 10%.

Neuro Applications

For this area, we spoke to Dr. McKinney at HCMC.

Dr. McKinney, as a radiologist, considered it very unlikely this issue would cause someone harm in the Neuro applications. This is due to the low percentage of studies that exhibit this behavior along with his expectation that the Vitrea

application would not be the only tool used when diagnosing a patient.

Dr. McKinney provided a scenario in which an aneurysm was being reviewed and said that treatment plans could change, based on a determination of whether the aneurysm is less than or greater than 5mm in size. Vitrea rounds to the nearest .1mm, so there is a .05mm (1%) margin of error built into the product.

Neuro Intevention

For this area, we spoke with Dr. Bharathi Jagadeesan at the University of Minnesota. He discussed three areas where length and volume measurements are used.

- Aneurysm
  - Dr. Jagadeesan was able to provide the Interventionalist's side to the radiologist perspective Dr. McKinney gave to us. Dr. Jagadeesan confirmed Dr. McKinney's statement that treatment could differ depending on whether the aneurysm is larger or smaller than 5mm. When asked what type of margin of error he would be comfortable with, he said he needs the measurement to be within .5mm, which, for a 5mm measurement, is 10%. Dr. Jagadeesan felt that greater than a 10% margin of error could lead to incorrect treatment.
- Pipeline Embolization
  - This procedure involves implanting a pipeline stent for intracranial aneurysms. This device is very precise and can only accommodate a measurement error of less than .25mm. This is because the device itself can expand up to .25mm in diameter. Dr. Jagadeesan believes measurements for this procedure must be within 5%, without causing risk to the patient.
- Tumors
  - When measuring tumors, Dr. Jagadeesan's opinion is that a 10% margin of error would be acceptable and not impact treatment. However, in a comparative study (prior and current), a growth or shrinkage of 5% between the two studies would be clinically significant, so the margin of error in the prior study must be within 5% of the margin of error in the current study.

Additional Notes:

- 10 of the most severely rotated studies were reviewed at MIR
  - Each series had at least one other series within the study that was not impacted by the error. There was not a study viewed were the only series available was a series that would produce incorrect measurements.
- We scanned all of Vital's internal datasets and found 46 datasets out of 25,306 (0.182%) that exhibited the error. Specific percentages are below:
  - 1 series (1 patient) with length error approximately 3% (area/volume errors of up to 6%)
  - 3 series (2 patients) with length error approximately 2% (area/volume errors of up to 4%)

- 7 series (4 patients) with length error approximately 0.5% (area/volume errors of up to 1%)
- 35 series (21 patients) with length error greater than 0% but less than 0.5%

Summary of Probability of Occurrence of Harm

The table below summarizes the margins of error provided to us by the doctors we spoke with and the volumes that exceed that margin of error. The percentages are based on a total of 238,083 volumes analyzed from MIR and Allegiance.

Exam	Margin of Error	Number of Volumes Exceeding the Margin of Error	Percent of Volumes Exceeding the Margin of Error
Liver Transplant	5% Volume	171	.0718%
Kidney Transplant	5% Volume	171	.0718%
Muscular Skeletal	10% Length	6	.0025%
Aneurysm	10% Length	6	.0025%
Pipeline Embolization	5% Length	28	.0118%
Brain Tumor	10% Volume	28	.0118%
Tumor Comparison*	5% Volume	171	.0718%

*This error is a relative error between the prior and the current series. The # of volumes exceeding the margin of error assumes one volume is affected, while the other is unaffected, which may not always be the case

The length and volume tools can be used for any type of exam and we only have a subset of those exams identified. Because of this limitation in the analysis, we cannot get an inclusive list of all exams and their acceptable margins of error. Therefore, in calculating the probability of occurrence of harm, the largest incidence of error identified is being used. Data shows .0718% of studies exhibit errors beyond tolerated levels, based on the tolerance levels for errors in kidney transplantation, liver transplantation and tumor comparison. This calculation means that the workflow that could cause the error is “probable,” under our standards for probability. Based on reviews of the datasets exhibiting the error, conversations with doctors and internal knowledge, it is expected that not every dataset with the error, even a significant error, is used in patient care or affects

a treatment plan. For example, it is expected that not every dataset where rotation is made at the scanner will be examined through use of Vitrea, even if the dataset resides within VIMS. It is also expected that surgery like kidney or liver transplantation would not be performed based solely on the measurements provided by Vitrea. Further, as Dr. McKinney states, often other modalities will be used and radiologists, the primary users of Vitrea, will rely on other knowledge and information, which may lessen the impact of this error However, these mitigating factors must be weighed against other factors. Among these factors are the following:

- Customers are producing volumes that exceed identified acceptable margins of error and storing them in VIMS;
- The incorrect volumes are loadable into Vitrea and can be measured through use of Vitrea;, and
- We cannot account for all potential clinical use cases for our general tools sufficiently to rule out that datasets exhibiting the error will be used in clinical practice.

Therefore, while we recognize the mitigating factors, which cause us to believe that the likelihood of the error occurring in the field is much less frequent than shown by the pure math of calculating the percentage of volumes showing the error, we have insufficient evidence to support a position that the probability of occurrence of harm is non-existent or improbable. Based on the calculations of probability provided by ISO 14971 and the frequency data we found from MIR and Allegiance, if one out of every 718 studies showing a material error lead to harm, the error would be considered remote or higher in probability. Because of the raw number of studies performed every year on Vitrea and the raw number of datasets showing a significant error, we are unable to find sufficient data to substantiate a frequency of harm lower than remote. Therefore, for purposes of further analysis, the **probability of occurrence of harm is considered to be at least REMOTE**.

Summary of Severity of Harm

The length and volume tools are part of the base Vitrea package and can be used in a variety of applications. During our discussion with the doctors mentioned above, it was clear the **severity of harm is CRITICAL.** These types of measurements may be used in transplant applications, aneurysm treatment, and other applications where a patient may end up going into surgery. Further, Vitrea may be used to determine whether a surgery is not needed or as a factor in determining a medication plan. The potential exists that this error could be a factor in an unnecessary surgery, a delayed surgery or an incorrect treatment plan. These events could result in a life threatening injury to a patient.

Risk Assessment

Risk Definitions

Severity Level Definitions

Catastrophic	Results in patient death
Critical	Results in permanent impairment or life-threatening injury
Serious	Results in injury or impairment requiring professional medical intervention
Minor	Results in temporary injury or impairment not requiring professional medical intervention
Negligible	Inconvenience or temporary discomfort

Probability Level Definitions

Frequent	>= 10^-3	Happens often
Probable	< 10^-3 and >= 10^-4	Likely to happen
Occasional	< 10^-4 and >= 10^-5	Can happen, but not likely
Remote	< 10^-5 and >= 10^-6	Unlikely to happen
Improbable	< 10^-6	Highly unlikely to happen

Risk Matrix

		Severity				
		Negligible	Minor	Serious	Critical	Catastrophic
Probability	Frequent	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
	Probable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
	Occasional	Acceptable	Acceptable	Unacceptable	Unnacceptable	Unacceptable
	Remote	Acceptable	Acceptable	Acceptable	Unacceptable	Unacceptable
	Improbable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Risk Assessment

After investigation, the issue is HAZARDOUS.

Hazard	Cause(s)	Mitigation(s)	Harm	Severity	Prob.	Risk Level
Misdiagnosis	Software Defect	None	Incorrect Treatment	Critical	Remote	Unacceptable

Action

Action	Rationale
CAPA and Field Action Required	**CAPA and Field Action Required**: The issue is hazardous and an unacceptable risk with serious health implications for patients or users. Therefore, additional mitigations should be explored and deployed to existing users.
CAPA Number	CAPA-12536

End of Document