# Commissioning of a Varian Six Degrees of Freedom (6DoF) Couch using the Standard Imaging HexaCheck Jig with the MIMI Phantom

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## Background

In 2018 and 2019 the NNUH commissioned two Varian Truebeam Linear Accelerators (Linacs) incorporating a 6 Degrees of Freedom (6DoF) couch able to correct for rotational errors in all directions (yaw, pitch, roll) in addition to translational errors.

This poster presents the NNUH's experience of commissioning the 6DoF couch using the MIMI phantom with the HexaCheck jig (Figure 1) from Standard Imaging [1]. The phantom can be rotated ±2.5° in all three directions, mimicking rotational patient set-up errors. Other published studies have used a cube phantom, an anthropomorphic phantom, the Isocal phantom and a specially constructed in-house robotic phantom to commission the 6DoF couch [2], [3], [4], [5].

The advantage of the HexaCheck-MIMI phantom is that it is designed so that the centre of the phantom will remain at isocentre when there is a rotational offset. This greatly simplifies data analysis and enables commissioning and QA in a busy clinical environment without the need to write extra software.

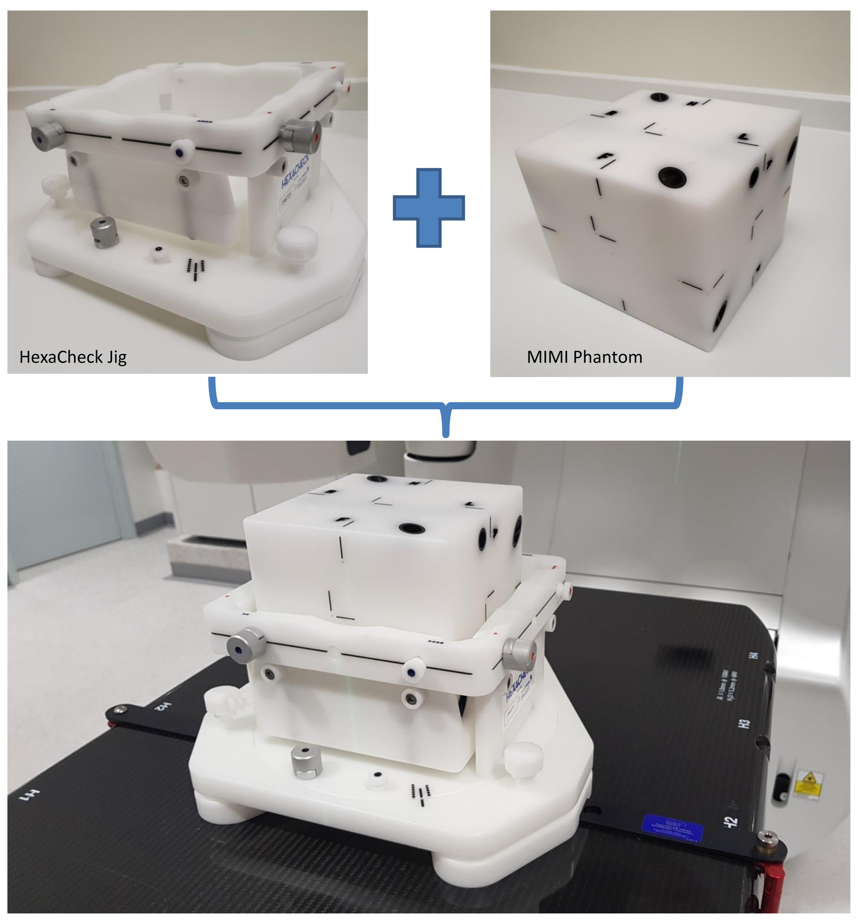


**Figure 1:** HexaCheck jig with the MIMI phantom positioned on the 6DoF couch.

## Methods and Materials

First the phantom was CT scanned in the neutral position (i.e. zero rotations) using the H&N protocol and the scan was used as reference for image matching.

Initial tests were carried out to test whether the NNUH's current method of H&N image matching using kV orthogonal pairs could provide sufficient accuracy for online matching compared to CBCT. The phantom was rotationally offset from the neutral position, then either a CBCT scan or a kV pair was taken and matched to the CT image.

The main part of the commissioning focused on CBCT imaging. The phantom was offset and imaged in every possible combination of rotational offset (27 combinations in total). Online corrections of the 6DoF couch were carried out to correct for the offset, then the phantom was reimaged. The residual error that was recorded gives a measure of the accuracy of the 6DoF couch correction.

## Results

The initial investigation of the accuracy of using matched pair kV images to correct for rotational shifts showed that the accuracy was significantly lower than using CBCT imaging and not adequate for accurate rotational corrections.

Main part of commissioning:

Linac 1 (commissioned in 2018)

The maximum residual rotation angle differences after the second CBCT scan were 0.1° for yaw, 0.3° for pitch and 0.1° for roll. The corresponding rotational deviations (mean±1SD) can be seen in Table 1.

The maximum residual translation differences were 0.5 mm Laterally (Left-Right direction), 0.4 mm Vertically (Anterior-Posterior direction) and 0.5 mm Longitudinally (Superior-Inferior direction). The corresponding translational deviations (mean±1SD) can be seen in Table 2.

Linac 2 (commissioned in 2019)

The maximum residual rotation angle differences after the second CBCT scan were 0.1° for yaw, 0.1° for pitch and 0.1° for roll. The corresponding rotational deviations (mean±1SD) can be seen in Table 1.

The maximum residual translation differences were 0.6 mm Laterally, 0.3 mm Vertically and 0.7 mm Longitudinally. The corresponding translational deviations (mean±1SD) can be seen in Table 2.

Figures 2 and 3 present histograms of the percentage (%) frequency of the residual error of the three rotational axes (for all the applied offsets) for Linac 1 and 2. No residual error greater than 0.3° was recorded.

Figures 4 and 5 present histograms of the percentage (%) frequency of the residual error of the three translational axes (for all the applied offsets) for Linac 1 and 2. No residual error greater than 0.7 mm was recorded.

**Table 1**: Corresponding rotational deviations (mean±1SD) deriving from calculations for all 27 different rotational offsets that were tested.

| Machine | Rotational Deviations (mean±1SD) (°) | | |
|---|---|---|---|
| | Yaw (°) | Pitch (°) | Roll (°) |
| Linac 1 | 0.00 ± 0.03 | 0.00 ± 0.11 | 0.00 ± 0.03 |
| Linac 2 | 0.01 ± 0.05 | 0.01 ± 0.08 | 0.00 ± 0.03 |

**Table 2:** Corresponding translational deviations (mean±1SD) deriving from calculations for all 27 different rotational offsets that were tested.

| Machine | Translational Deviations (mean±1SD) (mm) | | |
|---|---|---|---|
| | Lateral (mm) | Vertical (mm) | Longitudinal (mm) |
| Linac 1 | -0.02 ± 0.32 | 0.05 ± 0.30 | 0.07 ± 0.19 |
| Linac 2 | -0.17 ± 0.14 | -0.05 ± 0.11 | -0.03 ± 0.23 |

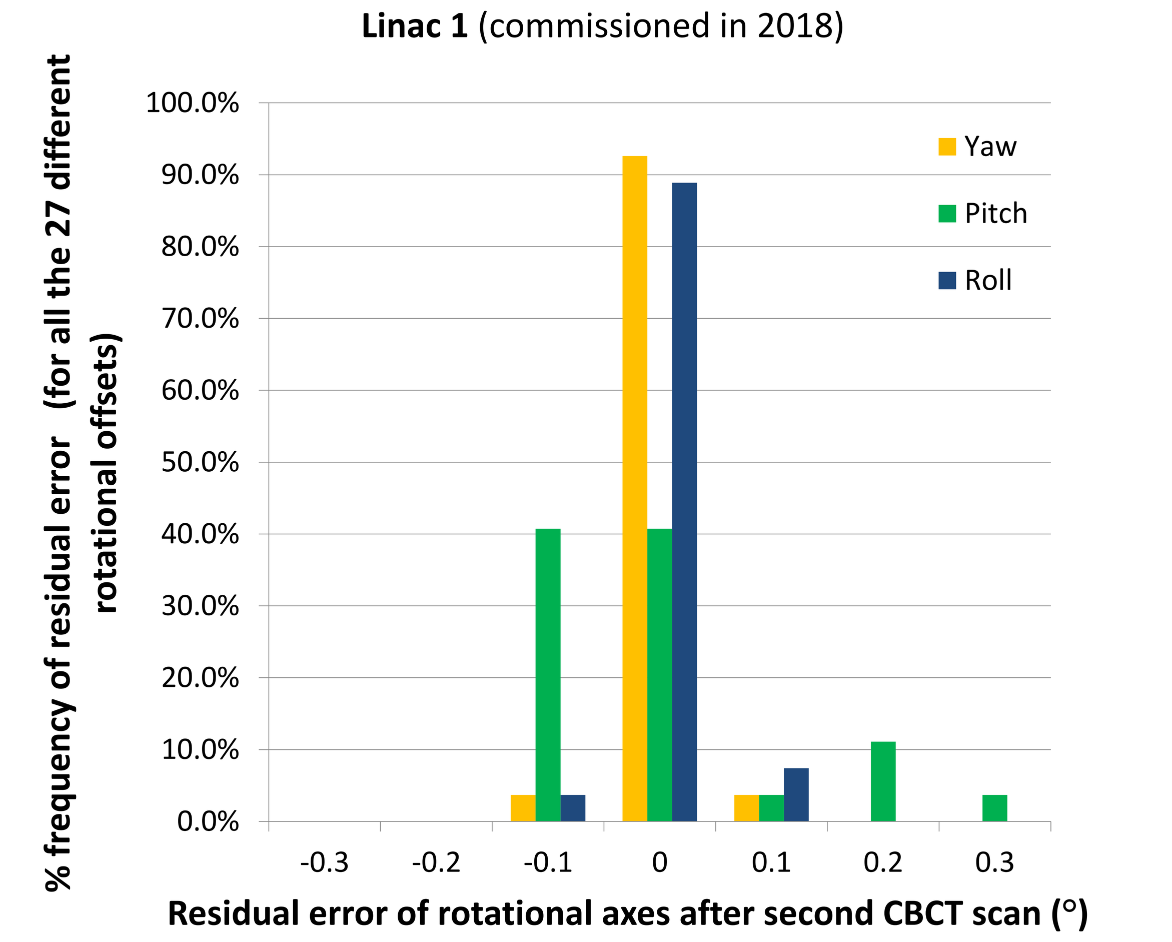


**Figure 2:** Histogram of the frequency of the residual error of the three rotational axes for the main part of the commissioning of the 6DoF couch on Linac 1.

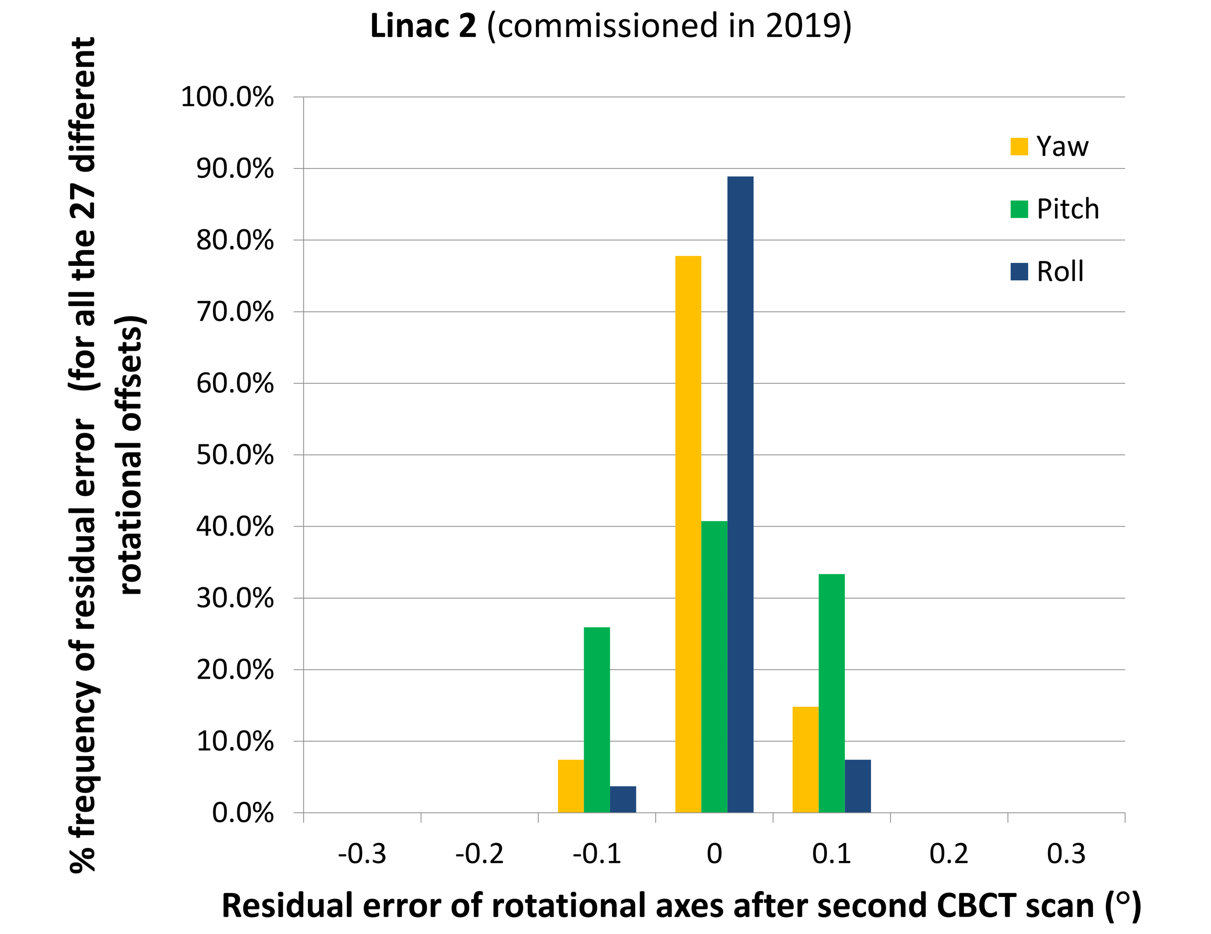


**Figure 3:** Histogram of the frequency of the residual error of the three rotational axes for the main part of the commissioning of the 6DoF couch on Linac 2.

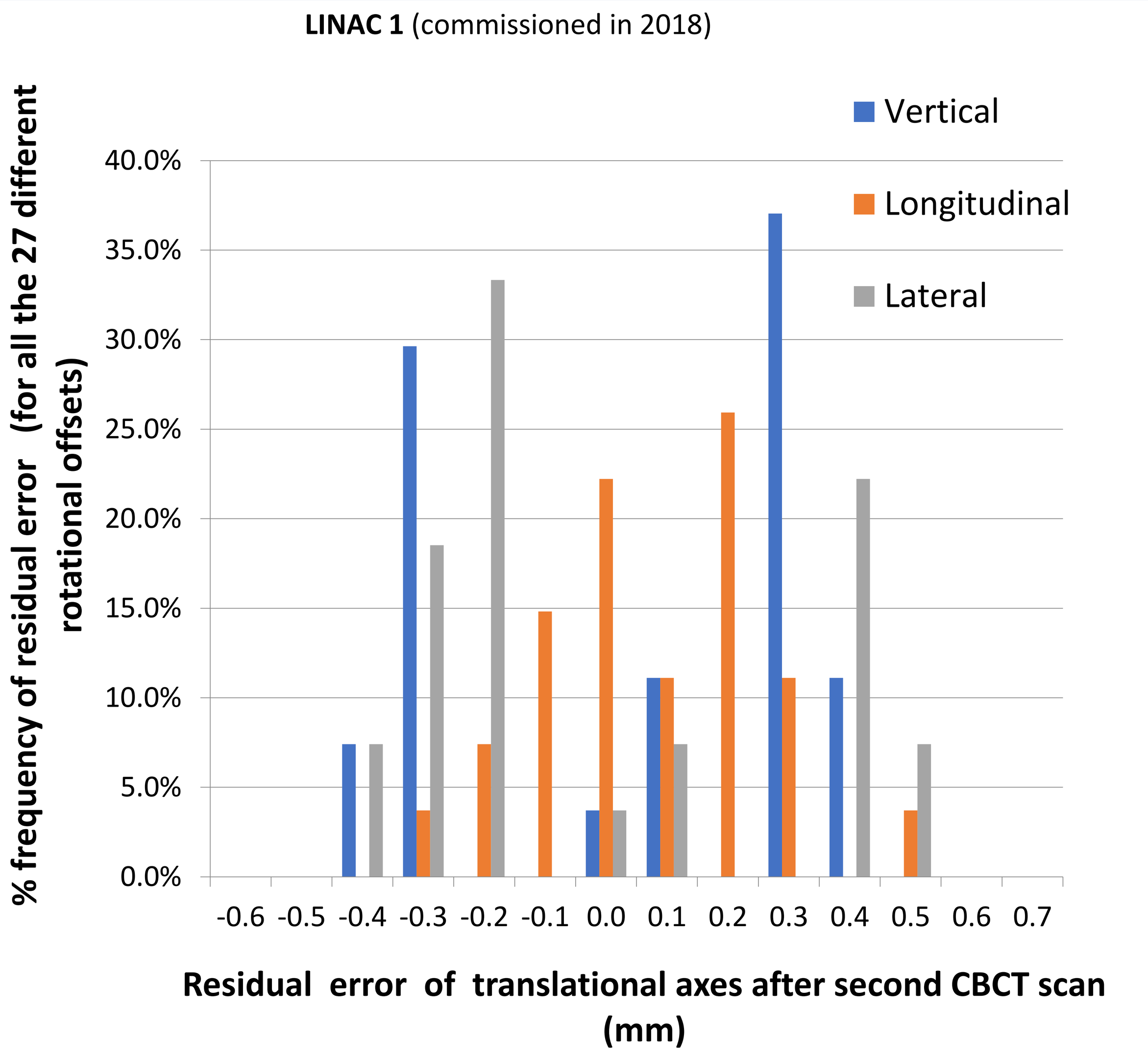


**Figure 4:** Histogram of the frequency of the residual error of the three translational axes for the main part of the commissioning of the 6DoF couch on Linac 1.

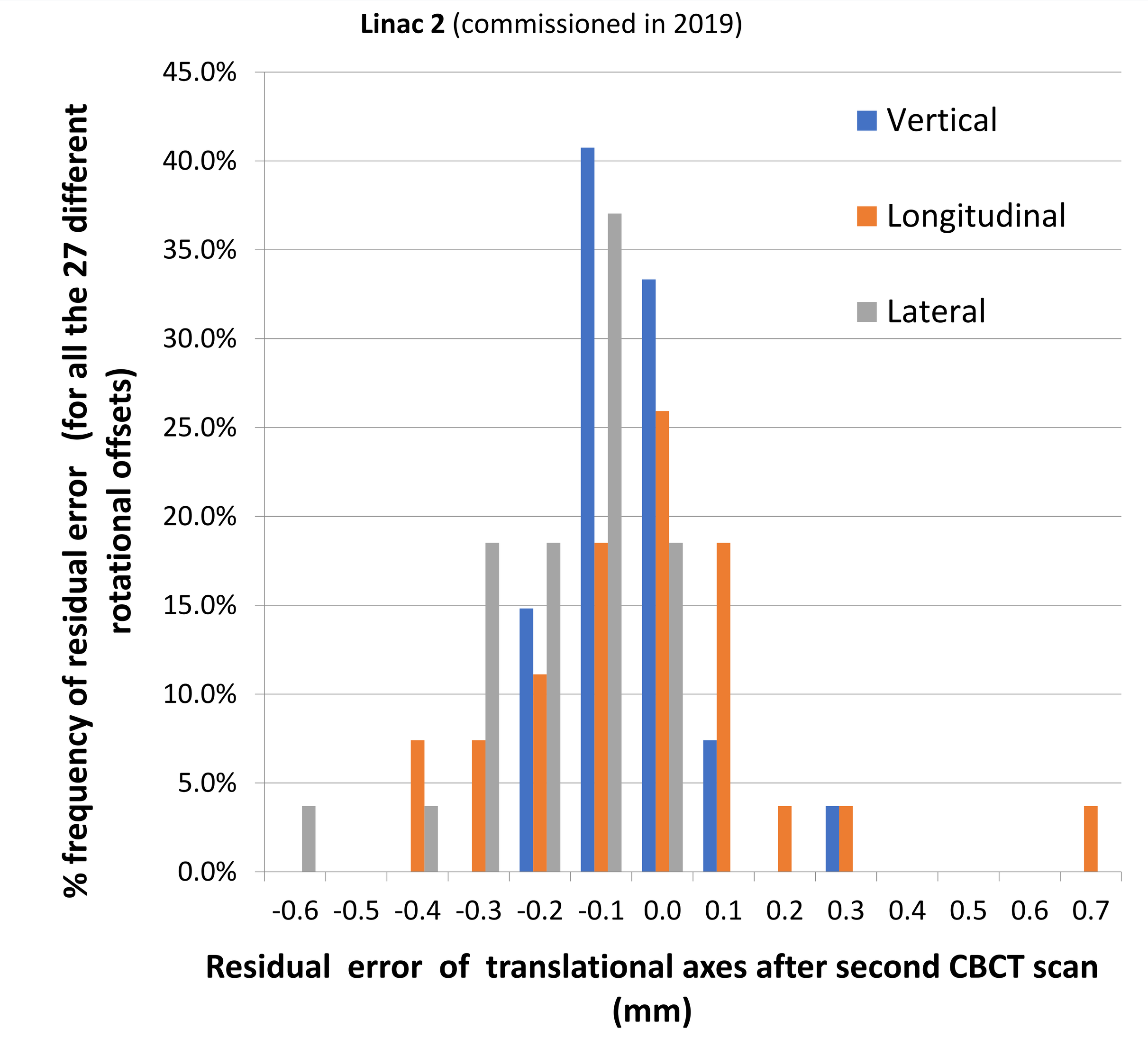


**Figure 5:** Histogram of the frequency of the residual error of the three translational axes for the main part of the commissioning of the 6DoF couch on Linac 2.

## Discussion

Comparison of the corresponding rotational and translational deviations between the two Linacs presents no significant difference. This shows consistency of the results from commissioning procedures and adds value to the accuracy of the Linacs' 6DoF modality.

Although no residual error (of the three rotational axes) greater than 0.3° was recorded for any of the two Linacs, the histogram for Linac 2 (Figure 3) presents "tighter" distribution than the one for Linac 1 (Figure 2). In the same fashion, although no residual error (of the three translational axes) greater than 0.7 mm was recorded for any of the two Linacs, the histogram for Linac 2 (Figure 5) presents "tighter" distribution than the one for Linac 1 (Figure 4). Both the above observations could indicate greater accuracy of the 6DoF couch modality for Linac 2 compared to Linac 1.

## Conclusions

This commissioning work has shown that rotational errors of less than 0.3° and translational errors of less than 1 mm are possible with the 6DoF couch using CBCT imaging. These results are the same order of magnitude as other studies using different phantoms and methods [2]. This level of accuracy is warranted for clinical radiotherapy utilization and the tolerance of the weekly QA of the couch was set at ±0.5°. In contrast, the NNUH's current method of using kV pairs for H&N is not accurate enough for applying rotational corrections. Future work will investigate the accuracy of 6DoF couch modality when using low dose CBCT imaging protocols.

## Contact

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## References

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