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Comparison among four immobilization devices for whole breast irradiation with Helical Tomotherapy

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Abstract

Purpose: To evaluate the repositioning accuracy of 4 immobilization devices (ID) used for whole breast Helical Tomotherapy treatments: arm float with VacFix[®] (Par Scientific, Denmark), all-in-one[®] (AIO[®]) system (Orfit, Belgium), MacroCast thermoplastic mask (Macromedics, [The Netherlands](#)) and BlueBag[®] system with Arm-Shuttle (Elekta, Sweden).

Materials and Methods: Twenty four women with breast cancer with PTV including the breast/chest wall and lymph nodes were involved in this study (6 women per group). Pretreatment registration results were first collected using automatic bone registration+manual adjustment on the vertebra followed by independent registrations on different ROIs representing each treated area (axillary, mammary chain, clavicular, breast/chest wall). The differences in translations and rotations between reference registration and the above mentioned ROIs were calculated. A total of 120 MVCT images were analyzed.

Results: Significant differences were found between IDs ($p < 0.0001$), ROIs ($p = 0.0002$) and the session number ($p < 0.0001$) on the observed shifts, when examining 3D translation vectors. 3D-vectors were significantly lower for the BlueBag[®] than for the VacFix[®] or for the AIO[®] ($p < 0.0001$), but differences were not significant compared to the mask ($p = 0.674$). Finally, setup margins were overall smaller for the BlueBag[®] than for other IDs, with values ranging from 1.53-1.91mm on the mammary chain area, 4.52-6.07mm on the clavicular area, 2.71-4.62mm on the axillary area, and 3.39-5.10mm on the breast.

Conclusion: We demonstrated in this study that the BlueBag[®] combined with arm shuttle is a robust solution for breast and nodes immobilization during HT treatments.

Keywords : Breast cancer, Tomotherapy, Immobilisation device

Introduction

Breast carcinoma is the most common malignancy in females. The estimated age-adjusted annual incidence of breast cancer in 40 European countries was 94.2 out of 100 000 in 2012 [1]. Adjuvant breast radiation therapy is a standard of care after both mastectomy and conservative breast surgery aiming to improve local control and survival [2-3]. The benefit of lymph node irradiation (mammary chain (MC), supra and infra clavicular nodes) in patients with axillary lymph nodes involvement or at high risk of relapse has been shown to improve survival in various clinical trials [4].

Routine breast cancer patients are irradiated using three-dimensional conformal radiation therapy (3D-CRT). However using such technique in breast and nodes and other complex cases (patient with unfavourable anatomy) may lead to suboptimal target coverage or high mean dose to the surrounding organs at risks (OARs) (heart or homolateral lung). Hence different dosimetric studies have shown that volumetric modulated arc therapy (VMAT) and Helical Tomotherapy (HT) techniques were able to improve [planning](#) targets volumes (PTV) coverages, thus allowing better dose homogeneity compared to 3D-CRT [5-6]. Furthermore, a recent retrospective study involving 66 patients with either locally advanced and/or metastatic breast cancer showed that HT was well tolerated and compatible with a multimodal strategy that includes concurrent systemic treatments [7]. Conversely, HT and VMAT treatments lead to an increase of low doses to the OARs raising the possibility of greater risk for secondary malignancies [8-9].

To be safely and efficiently delivered, VMAT and HT treatments must be performed with good accuracy because of the presence of steep dose gradients. Otherwise high doses may be delivered to the neighbouring organs. Therefore, highly conformal dose distributions necessitate patient immobilization with reliable and accurate device combined with performing in-room imaging technique. With MegaVoltage CT (MVCT) image guidance (Accuray, [USA](#)) used on HT devices both translational and rotational setup errors can be detected, which improves the interfraction positioning. Patients treated for breast cancers with nodes involvements are routinely immobilized using breast boards such as CIVCO (Coralville, IA) wing-boards [10-11]. However, these devices may not be appropriate for HT treatment first because of the [increased treatment time](#) (around 20 min) in which the patient can either slide down [due to the panel board inclination](#) or her arm can collapse and move into the beam. In addition, overweight patients may not pass in the HT tunnel.

To our knowledge, there are no accepted guidelines for reproducible immobilization during the irradiation of breast cancer with nodes involvement. Therefore, to optimize the interfraction positioning and to minimize intrafraction motions in HT treatments, we decided to evaluate the repositioning accuracy of 4 immobilization devices (ID): arm float with VacFix[®] (Par Scientific, Denmark), all-in-one (AIO[®]) system (Orfit industries, Belgium), MacroCast thermoplastic mask (Macromedics, [The Netherlands](#)) and BlueBag[®] system with Arm-Shuttle (Elekta, Sweden). Investigations were performed by analysing pre-treatment MVCT images and examining translations and rotations obtained in all directions for different selected regions of interest (ROIs) for registration. The multiple ROIs registration method helped establishing which of the ID enabled minimizing local deformations. Setup margins were finally calculated and compared in function of the selected IDs and ROIs.

Materials and Methods

Patient group

Twenty four patients with breast cancer were selected in this study, irrespective of tumor stage and location. All the patients received whole breast HT treatments involving breast or chest wall, axillary lymph nodes, MC, supra and infra clavicular nodes. Contouring of the different nodes was done according to the guidelines for target volume delineation in breast cancer of the new European Society for Radiotherapy and Oncology (ESTRO) [12]. Patients were scanned in supine position and breathed freely during simulation and treatment. The 24 patients were divided into 4 groups of 6 patients, treated with the different immobilization devices (IDs) listed below:

- Arm float with VacFix[®] and bra (Vac+bra) (Fig 1A)
- All-in-one[®] (AIO[®]) device + [thoracic thermoplastic mask](#) (Fig 1B)
- Five-points thermoplastic mask macrocast[®] and standard head rest (mask) (Fig 1C)
- BlueBag[®] system with armshuttle (Fig 1D)

All the patients had an additional knee support (Civco Medical Solutions, Kolona, USA) for stability and comfort. [Patients were included randomly in the 4 groups. Patients characteristics are listed in Table 1.](#)

Two chest walls and 4 breasts were included in each group immobilized with the BlueBag[®] and Vac+fix, whereas the 2 other groups were composed of 3 chest wall and 3 breasts. The Body Mass Index (BMI) and the bra cap size were collected for each patient.

Patient setup methodology

For treatment, the patients were first positioned using localization lines on the mask or on the skin depending on the immobilization devices. Prior to the delivery, MVCT images were performed using the imaging device from the HT (Accuray[®], USA). MVCT scans were acquired according to our standards, on the basis of a daily MVCT. **For the first treatment fraction, then once a week**, the length of the MVCT scan was chosen to cover the length of the breast and supra clavicular areas. **The other days, only partial MVCT was done for quick patient setup**. Imaging was usually carried out using the “coarse” settings which gives slices at 6-mm spacing. The estimated delivered dose was less than 1 cGy per acquisition as determined from measurements. The reconstruction Field of view is around 39 cm which is sometimes too small to cover the edge of the patient. However the whole cohort was not concerned by this issue. **Only MVCTs including all PTVs areas were analysed which represents a total of 120 MVCT scans and 30 MVCT images per immobilization device**. In routine, the registration between the planning CT and **MVCT** is performed first using the automatic bone-matching algorithm followed by manual adjustment on the vertebra. For the present study, all the data were processed after the end of the patients treatments using different ROIs as described below.

Multiple regions of interest registration

During the treatment, planning CT images were matched online with the daily MV images by a skilled therapist using the automatic bone-matching algorithm followed by a visual validation of the registration on the vertebra and spine region. Registrations based on 4 different ROIs consisting in the different treatment areas involved (Breast/chest wall, axillary lymph nodes, MC, supra-infra clavicular nodes) were then performed **offline by the same therapist for all patients**. To do this, an automatic bone matching followed by a manual registration on the selected ROI was done.

Data processing

The repositioning accuracy of the different IDs was first assessed by calculating the translation vectors for each ID and each registration ROI [separately after patient setup on the reference skin markers](#), using the following formula:

$$T = [Tx^2+Ty^2+Tz^2]^{1/2}$$

Tx, Ty and Tz representing the translation values obtained in the left-right (LR), supero-inferior (SI) and antero-posterior (AP) directions, respectively. [This enabled us to see if the different shifts were constant or if they were increasing with the treatment duration \(thus demonstrating that the ID was not reliable for maintaining reference position during the whole treatment\)](#). Furthermore it allowed us to determine which ID minimized local deformation for each ROI. Rotations were thereafter calculated.

[Residual setup errors resulting from the subtraction of the shifts obtained using a specific ROI for registration and reference matching based on automatic bone registration+manual adjustment](#) were calculated according to the methodology described by *van Herk et al.* [13]. The interfraction displacements were separated in a systematic (Σ) and a random (σ) uncorrected error for each of the 4 breast supports and each ROI. For each patient the average of the displacements (μ_p) and the standard deviation (SD_p) were calculated for each ROI in each direction and over all fractions. For each ID, each ROI, and each direction, the group mean error (μ) was then calculated by averaging μ_p . The systematic errors (Σ) were then calculated as the standard deviation of the μ_p of all patients with the same ID. The random errors (σ) were calculated as the root-mean-square over all SD_p .

[Then each ROI was alternatnively considered as the reference ROI for registration and the same methology, as described above, was applied to calculate \$\Sigma\$ and \$\sigma\$.](#)

After registration considering successively each ROIs as the reference, margins resulting from uncertain setup alone, were finally estimated from the systematic and random variations according to van Herk margin equation: $M = 2.5\Sigma+0.7\sigma$. This formula assumes that a minimum of 95% of the prescribed dose covers the volume for 90% of the patient population [13].

Statistical methods

To examine whether surgery (chest wall or breast) or bra cap size had an impact on the results, we used a Fisher Exact test, whereas, for the BMI, we used a Kruskal-Wallis test. To evaluate the impact of the ROIs, immobilization devices and session number on the 3D translation vector, a general linear model analysis (3 way-ANOVA analysis) was performed. This model analyses the scalar product of 3 dimension positioning (X, Y, Z) of the 4 different ROIs (Breast/chest wall, axillary lymph nodes, MC, supra-infra clavicular nodes), of the 4 different immobilization devices (AIO[®], VacFix, Blue Bag arm shuttle, Macrocast thermoplastic) and of the session's number (1, 5, 10, 15, 20, 25). Statistical analyses have been performed using SAS software version 9.4. Differences were considered as significant for p values <0.05.

Results

Even if the sample per group is small to reach a definitive conclusion, no difference was found between the 4 IDs in terms of number of chest walls or breasts ($p=1$), in terms of bra cap for the breast treatment ($p=0.268$), and in terms of BMI for all the patients ($p=0.414$).

The absolute number of translations and rotations with residual local errors exceeding 5mm and/or 3° after registration is shown in Fig 2 for each ID and each ROI. Translations and rotations were treated separately. The overall smallest number of translation warnings in all the ROIs were obtained for the BlueBag[®] (Fig 2A). Conversely, the AIO[®] system had the largest number of warnings, in particular when considering the ROIs encompassing axillary and breast/chest wall. The mask was efficient for the immobilization of the nodes but not for the breast/chest wall. Finally, the number of rotations warnings was generally more important with the mask than with other systems, the best results being obtained with the Vac+Bra (Fig 2B).

Three-dimensional translation vectors were then plotted for each day of treatment considering each reference ROI (Fig 3). Thanks to the 3 way-ANOVA, we found a significant impact of the ROI ($p = 0.0002$), of the ID ($p<0.0001$) and of the session's number ($p<0.0001$) on the observed shifts. We noticed a gradient for the displacements which increased during the treatment course. The Sidak post-hoc analysis showed that the 3D translation vector was significantly lower for the BlueBag[®] than for the Vac+Bra or for the AIO[®] ($p<0.0001$).

However the difference was not significant compared to the mask ($p=0.674$). Similarly, 3D translation vectors were significantly lower for the mask compared to the AIO[®] or to the Vac+Bra ($p<0.001$). Finally the 3D translation vectors were not significantly different between AIO[®] and Vac+Bra (0.912).

The **residual** interfraction displacements (translations and rotations) **obtained after automatic bone registration+manual ajustement** were then separated in a systematic (Σ) and random (σ) uncorrected error for the 4 IDs separately and for each registration box. The different translational and rotational setup shifts obtained are given in **Tables 2 and 3** for the RL, SI and AP directions in function of the ID used and the ROI selected for the image registration.

The average systematic translation shifts (μ) calculated over all the patients immobilized with the BlueBag[®] was less than 0.9mm (**Table 2**). Similarly, small μ values were also calculated for the AIO[®] and the Vac+Bra, with only 1 and 2 cases, respectively, where μ was found above 0.9mm. Conversely, larger μ values were generally obtained with the mask, especially in AP direction. Note that for the mask, the BlueBag[®] and AIO[®], the best results were obtained on MC nodes (small μ values combined with small ranges). When looking at the Σ values, they were below 2mm in most cases for all the IDs. Again, Σ values were low in all directions for the AIO[®] (≤ 0.45 mm), the mask (≤ 0.74 mm) and the BlueBag[®] (≤ 0.47 mm), when considering registrations in MC ROI. Finally, the σ values were generally found smaller for the BlueBag[®] (< 1.8 mm), compared to other IDs and smaller considering ROI on the MC for all IDs with the exception of the Mask. Note that the larger σ values were obtained for the Vac+Bra.

The rotational global positioning errors were thereafter examined (**Table 3**). The overall μ values calculated for all the IDs were small ($< 0.5^\circ$ for the Vac+Bra and the BlueBag[®]; $< 1^\circ$ for the AIO[®] and the mask). Σ and σ values were $\leq 1.76^\circ$ and $\leq 1.42^\circ$, respectively, whatever the ID or the ROI used. The Σ values were globally found smaller for the BlueBag[®] ($< 0.7^\circ$) than for other IDs. Note that, for the AIO[®] the Σ in AP direction was generally larger than in other directions, whereas for the mask and for the Vac+Bra, Σ was larger in SI and LR directions, respectively.

Finally, **after registration considering successively each ROI as the reference**, margins resulting from uncertain setup alone **were calculated (Table 4)**. Regarding the small volume of the MC and its proximity to the heart, we considered that margins above > 5 mm on this structure were unacceptable. Hence the best ROI for registration was the MC for the

Vac+Bra, the MC or Autobone registration+manual adjustment for the AOI, and autobone registration+manual adjustment for the Mask. For the BlueBag[®], registrations based on the MC or autobone+manual adjustment provided the best results. Note that, for this ID, margins were also found small using the axillary area as reference ROI, but margins around the MC were more important than with other ROIs. We also found that setup margins were overall smaller for the BlueBag[®] than for other IDs, with only 2 values being over 5mm, using autobone registration+manual adjustment, or the MC as reference ROI for registration. For the Vac+Bra, 3 values were over 6mm using the MC as reference ROI. For the AIO[®], using autobone registration+manual adjustment, important margins (maximum 9.44 mm for the breast/chest wall) were found in LR direction for all ROIs but MC, which highlights some difficulties for positioning patients in this direction. Finally, for the mask, using autobone registration+manual adjustment, large setup margins were obtained for the breast/chest wall (5.05 to 7.25 mm) and around axillary areas in LR (5.84mm) and SI (6.51mm) directions.

Discussion

The objective of this study was to evaluate the repositioning accuracy of 4 IDs dedicated to whole breast irradiation in HT. This is, to our knowledge, the only study comparing different IDs for breast or chest wall irradiation involving nodes, including axillary nodes, and using multiple ROIs registration method.

The provided results showed that there was a significant effect of the chosen ROIs, the IDs and the treatment session. Furthermore, there was a variation of the shifts, which increased through the treatment course, which can be attributed to a change in the morphology of the patient (the breast is usually growing as the number of treatment sessions progresses) and to the deterioration of the ID. Indeed, Thermoplastic masks and AIO[®] immobilization efficiency are likely to be directly impacted by anatomical changes such as weight loss or breast oedema whereas Bluebag[®] and VacFix mattress can show a diminution of their performance along the treatment course due to vacuum loss.

When the 3D translation vectors only were considered, significant differences between the IDs were observed, except between the BlueBag[®] and the mask, which were considered to be the best solutions. However calculated margins were significantly smaller for the BlueBag[®],

especially when considering the SI direction for all the ROIs with the exception of the MC, or when considering the margins around the breast/chest wall.

Few studies can be found in the literature about the evaluation of robustness of IDs for breast irradiation [10-11; 14-18]. Among them, *Probst et al* did a systematic review of different methods to immobilize breast without nodes involvement during irradiation [18]. Their conclusions were that additional support cushion below the knees was likely to enhance treatment accuracy, and that, using double arms up technique also increased patients' stability and decreased the volume of lung or heart within the treatment fields (for conformal radiation).

Among all the studies dealing with breast and nodes irradiation (more details on supplementary material I), patients were irradiated with the HT and the evaluation was based on CT/MVCT registration method in 2 studies only. Hence, similarly to our study, *Agostini et al* evaluated the robustness of the AIO[®] for breast and nodes (all but axillary) immobilization [10]. They assessed whether the additional thoracic thermoplastic immobilization, which was used in our study, could improve the reproductibility of treatment setup with this ID. Analysis of shift-roll data showed no improvement in the group of patients immobilized with the addition of thermoplastic mask. The day-to-day setup variation was found to be large, with σ values of 2.6, 3.4, and 4.2mm and Σ values of 3, 1.6, and 2.5mm in LR, SI, and AP directions, respectively. In our study, Σ and σ values were found smaller for this ID, whatever the considered ROI for registration. However, margins calculations showed that pretreatment positioning in LR was less robust than for the other studied IDs. Note that, for this ID, a more important ramp-up time was necessary for the therapists to be comfortable with the material.

In the second study dealing with HT irradiation of breast cancer, treatment delivery in supine position with the VacLok[®] system (CIVCO Medical Solutions, Kolona, USA) and headrest with both arm raised overhead was compared to irradiation using a prone breast technique [16]. The first immobilization technique was shown to be more stable than the one in prone position. The Σ values ranged between 1.4-2.8mm whereas the σ values ranged between 1.4-2.4mm. The mean 3D vectors was 7.6mm and 3D vectors ≥ 6 mm occurred in 66 % of cases. We obtained better results with the BlueBag[®] since mean 3D vectors were comprised between 2.79mm (day 1 of treatment) and 5.69mm (day 20).

Finally, some studies put forwards the patients comfort in the performance evaluation of immobilization devices, some evaluated two different harm positions [19]. Nalder et al.

compared positioning with or without vac-fix immobilization and the vac-fix device was better rated [20]. In our study, the comfort was not rated, but the question was asked and no patient reported discomfort. However we can assume that the mask is less comfortable than the 3 other immobilization devices.

Conclusions

By taking into account all the parameters, we demonstrated in this study that the BlueBag[®] combined with arm shuttle is the best ID for breast and nodes immobilization during HT treatments. The results obtained are consistent with the literature which generally recommends treating patients in supine position, with double arms up technique, and with cushions under the knees. In our practice, it has become our reference ID for treating breast cancer with the HT. However, in situations where patients are unable to move their arms, the mask is a good alternative. Up to now, we use treatment margins of 5mm in all directions for breast and nodes irradiation in HT. The next step is to adapt margins to the different lymph nodes areas for patients immobilized with the BlueBag[®]. Indeed, for the MC, setup margins were found less than 2mm in all directions. Hence reducing margins from 5 to 3mm could be a good compromise between margin found in this study and our current practice. This would be a first step in margin reduction in this area.

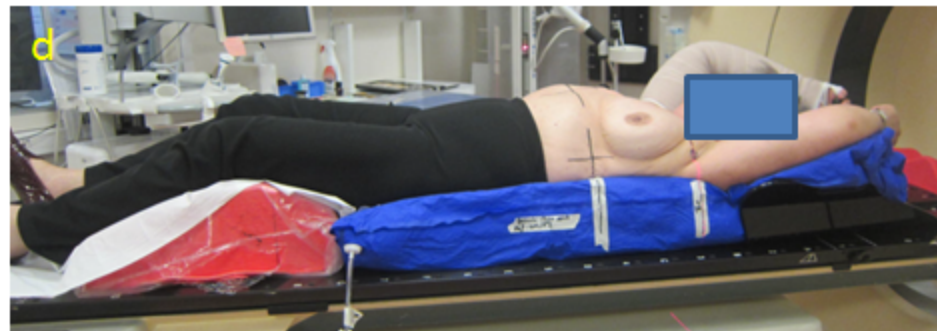
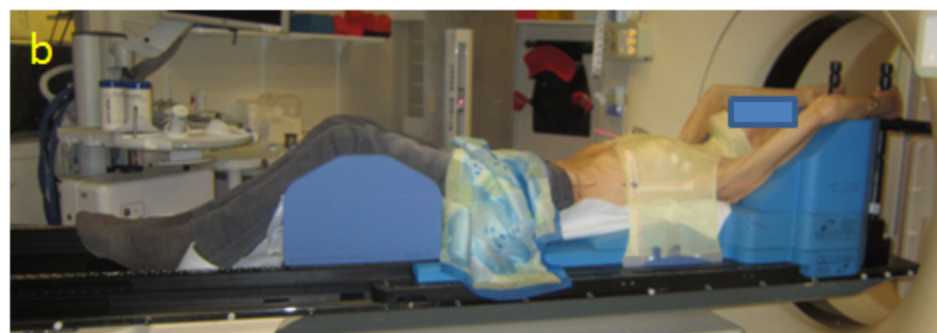
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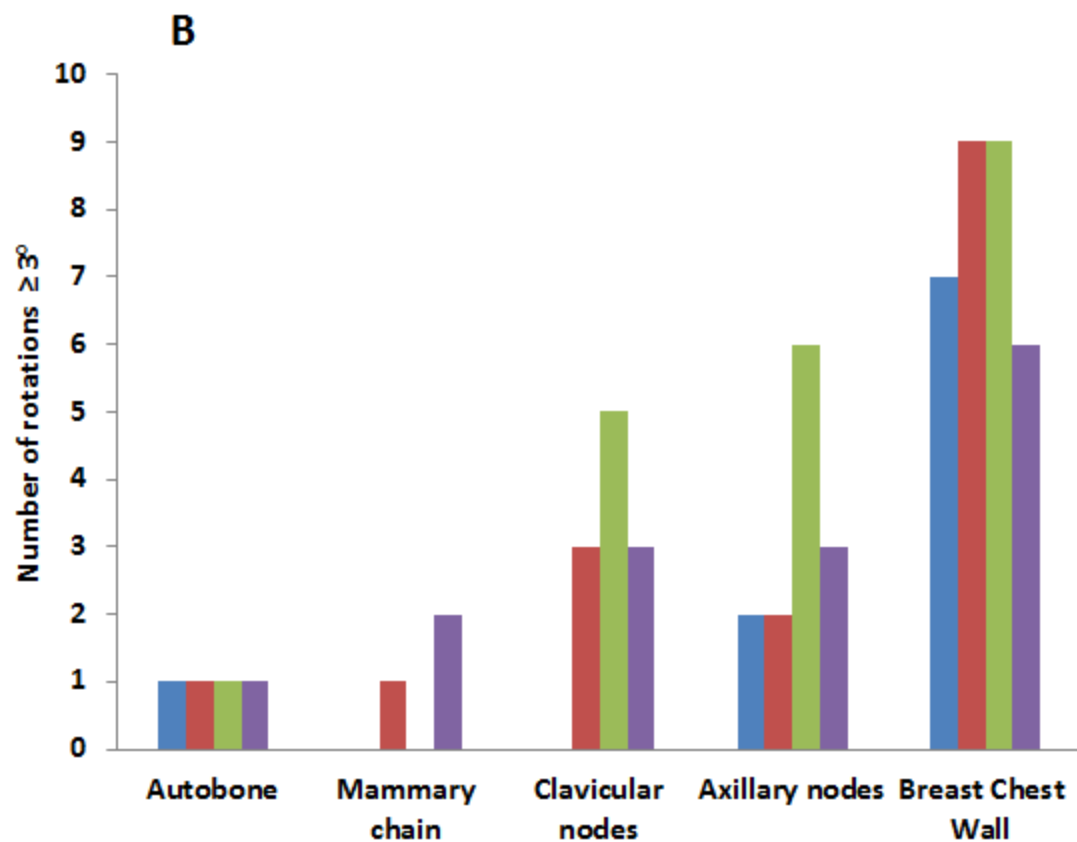
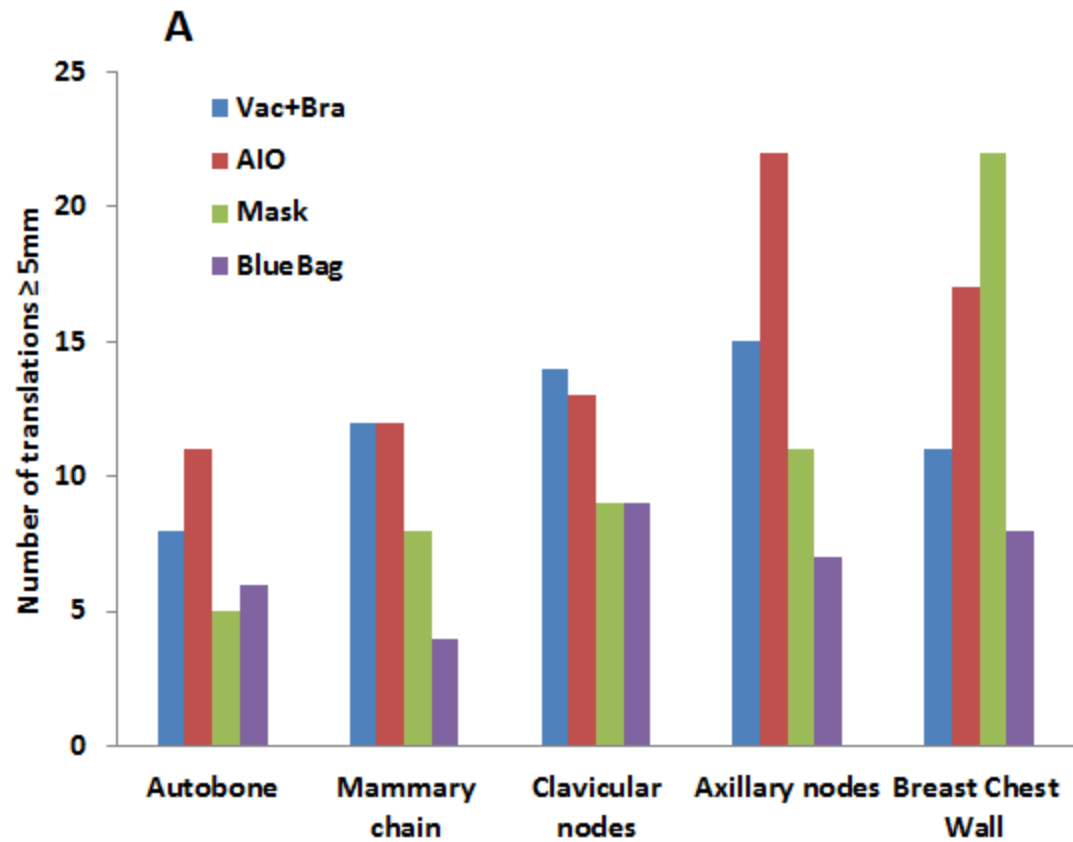
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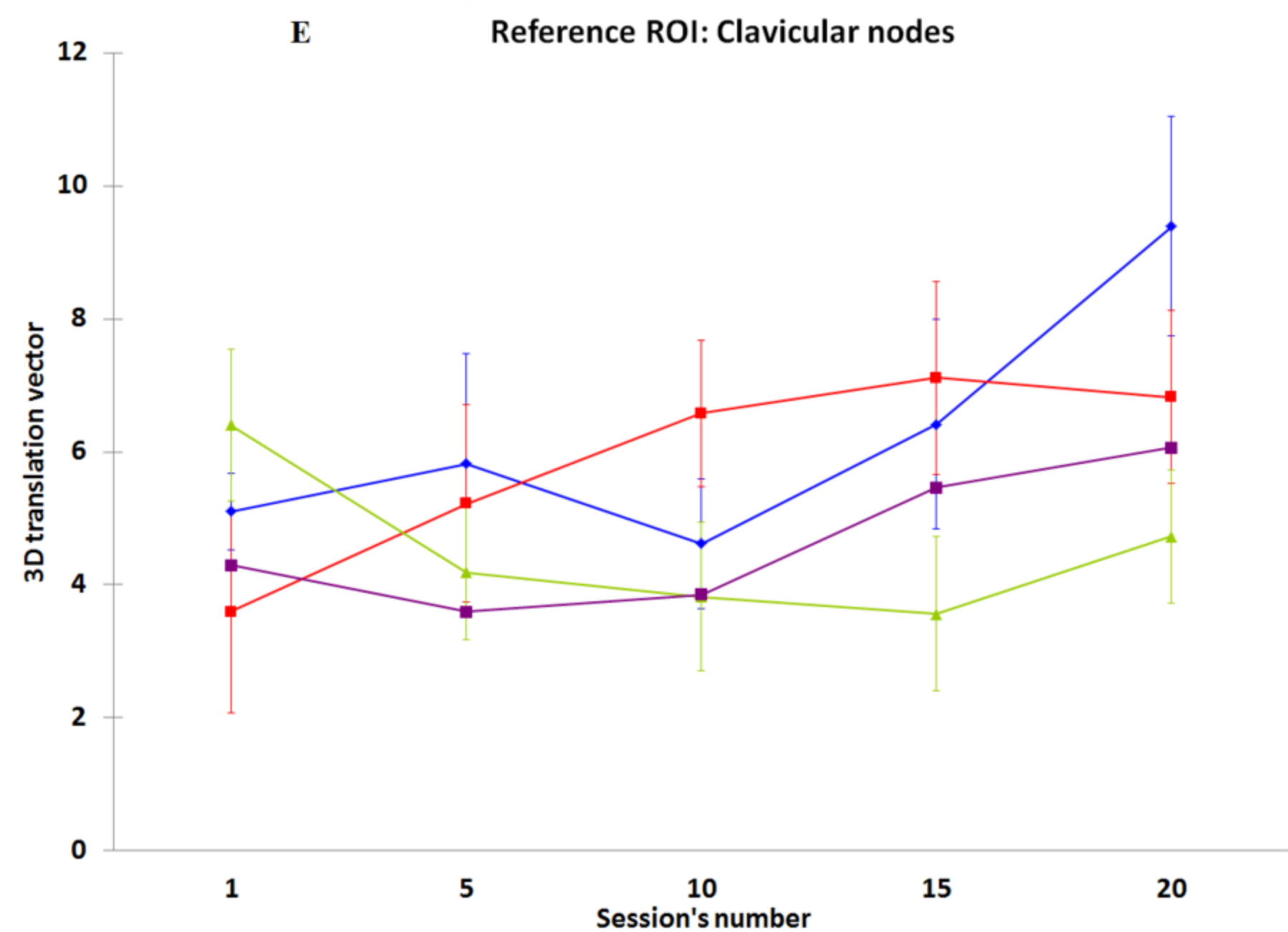
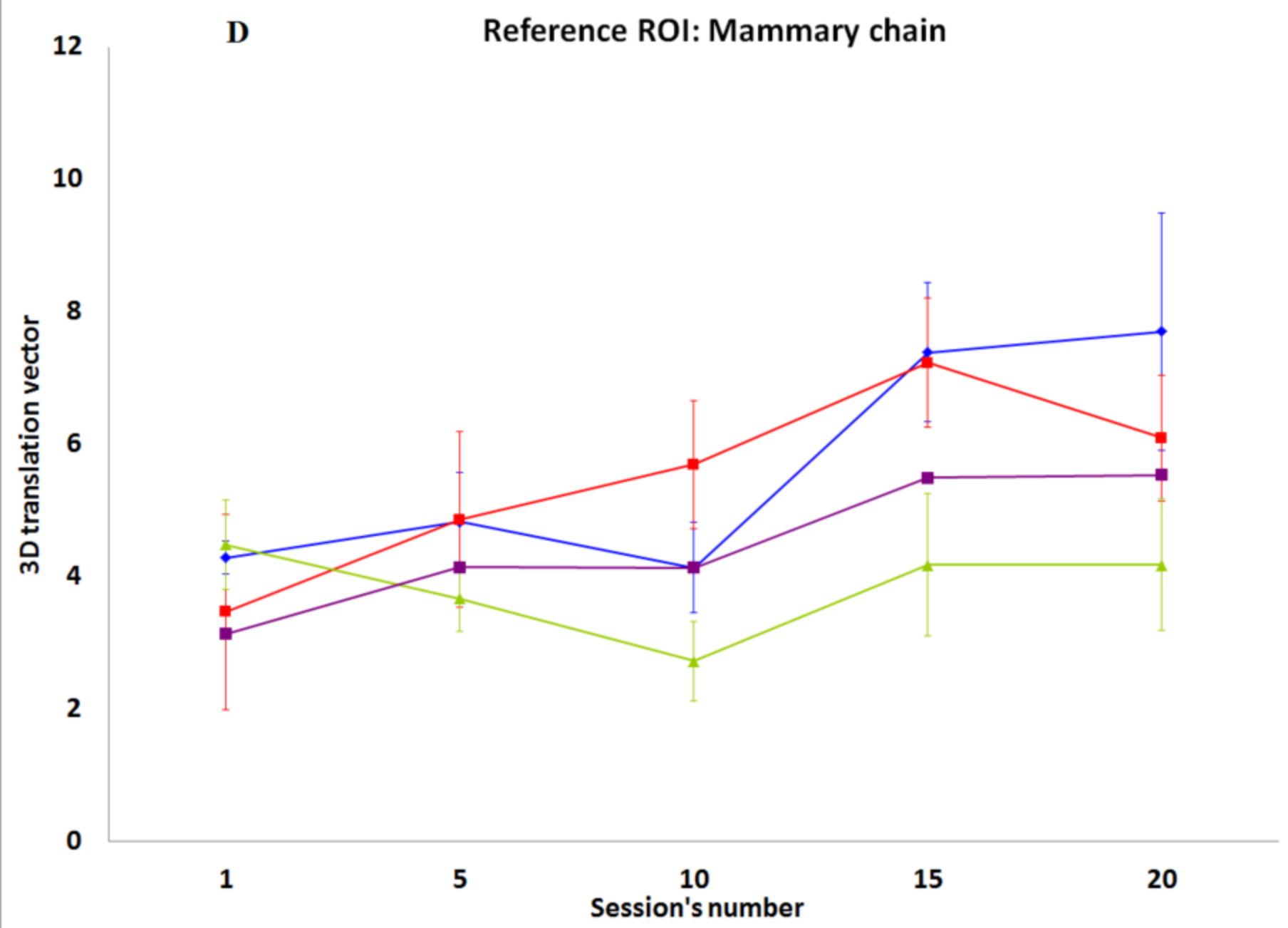
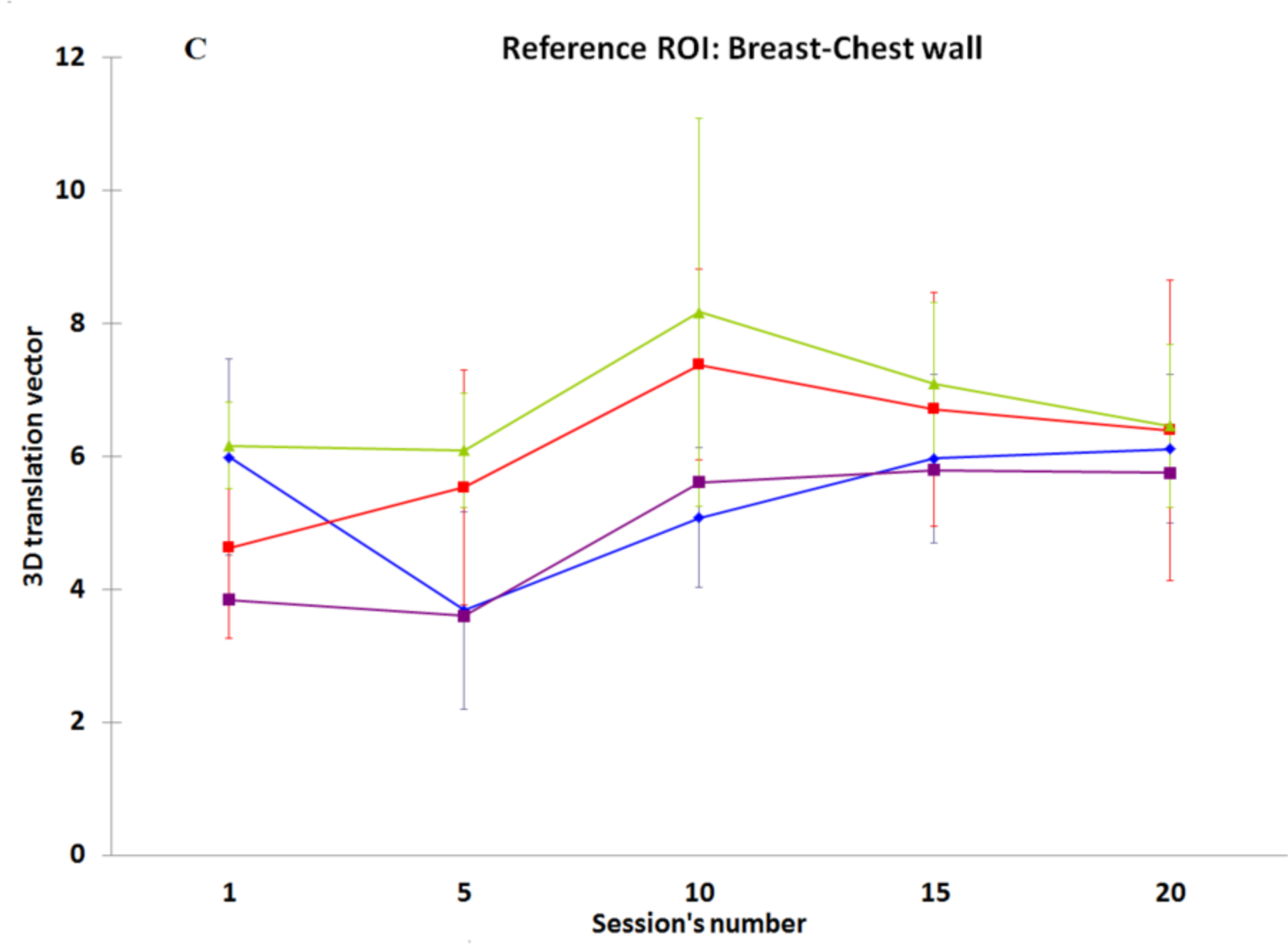
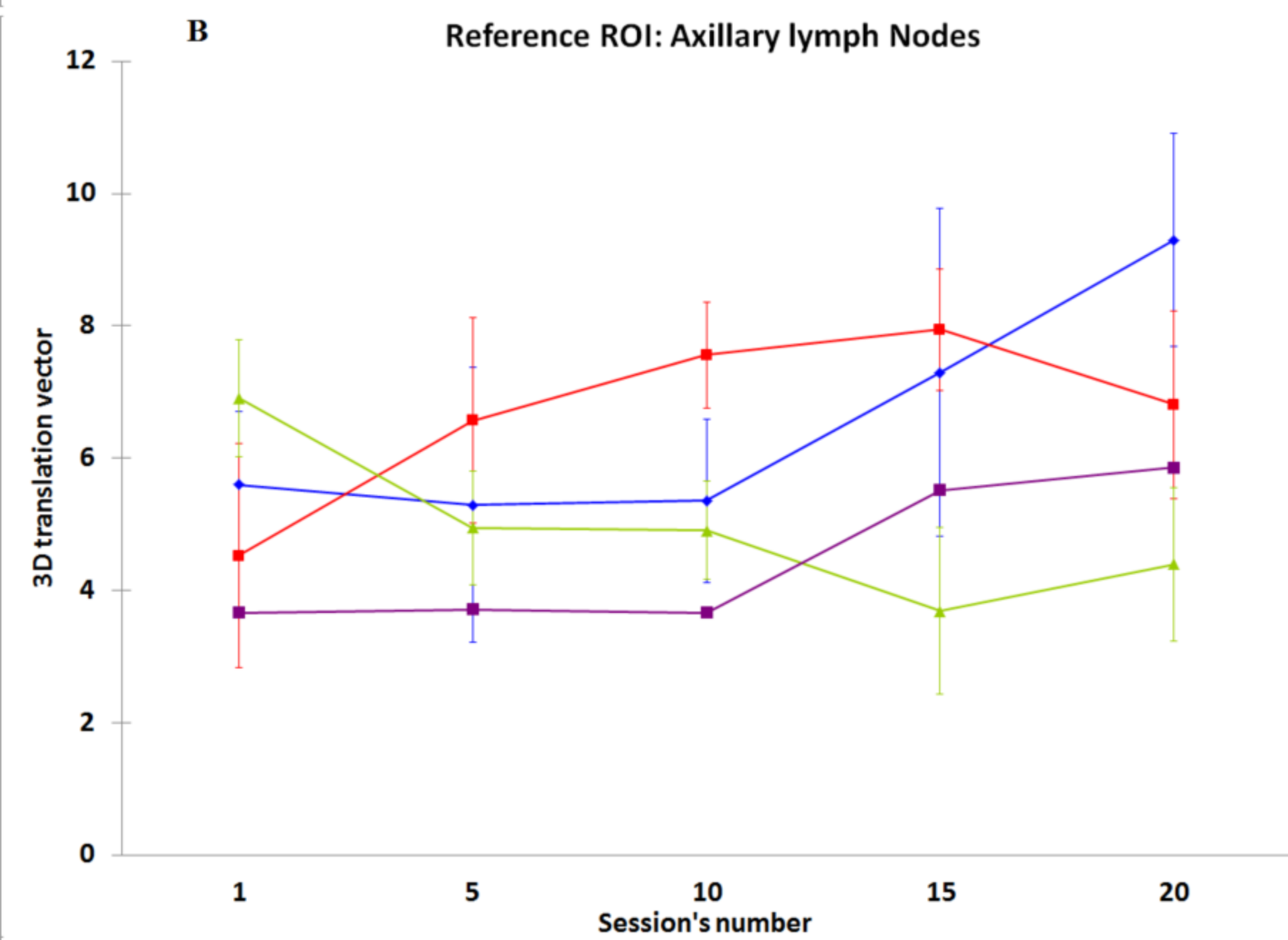
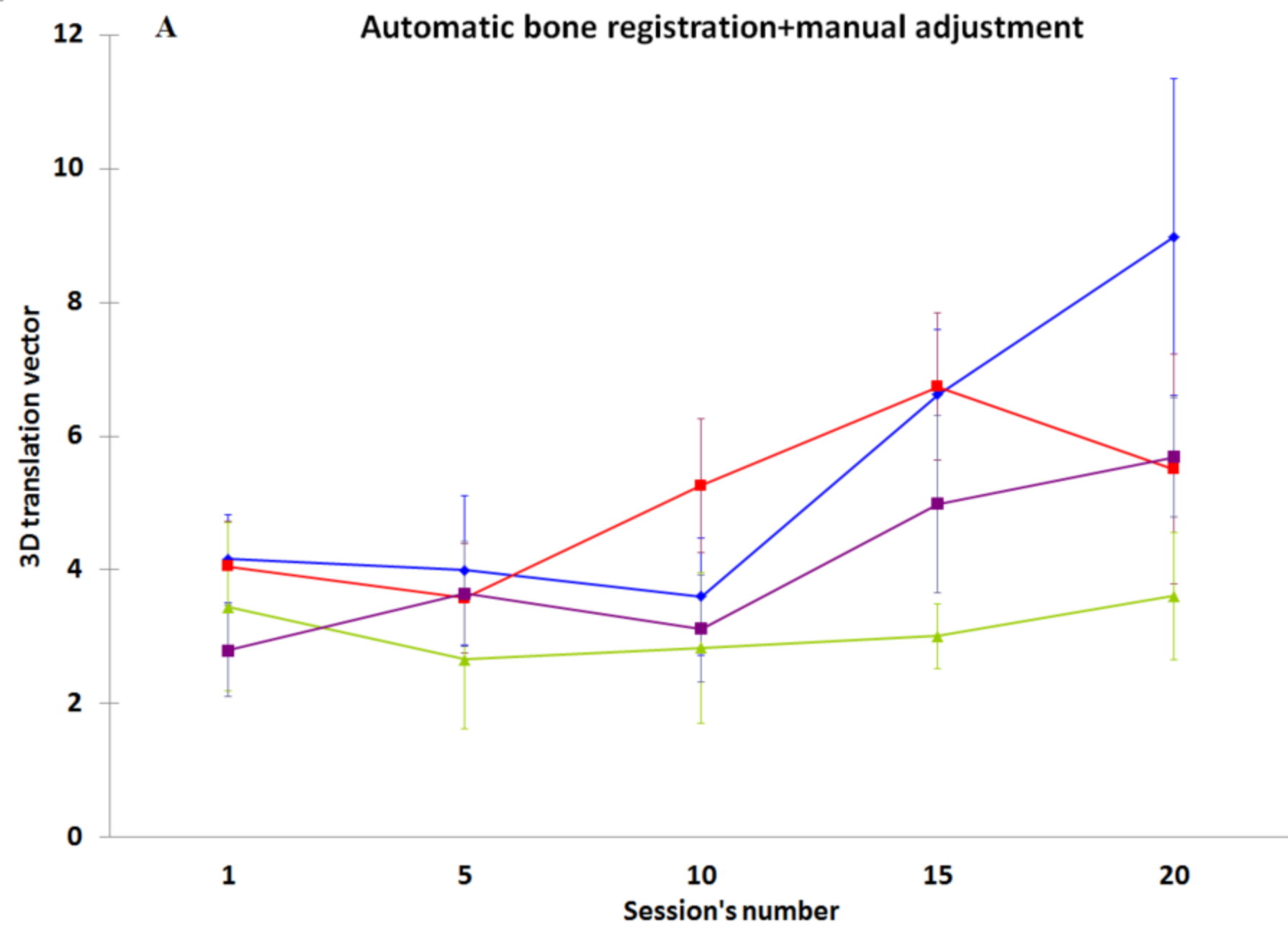


Table 1 . Patients' characters.

Groups	AIO system	Bluebag system with arm shuttle	Macrocast thermoplastic masq	Arm float with VacFix
Number of patients	6	6	6	6
Median age (years)	72.5 (49-83)	66.5 (55-72)	63.5 (44-77)	56.5 (51-83)
Median BMI (kg/m²)	30.5 (17-33)	26 (21.6-37)	32 (22-36)	28,2 (21-32)
Breast or chest wall	3 3	3 3	3 3	4 2
Bra cap				
B	1	0	1	1
C	0	3	0	1
D	2	0	2	2
Treated side				
Left	4	4	3	3
Right	2	3	2	3
Bilateral	0	0	1	0

Table 2. Translational global positioning errors resulting from automatic bone registration and manual adjustment

Immobilisation Device	Average systematic errors μ (mm) [range]			Systematic errors SDs Σ (mm)			Average random errors RMS σ (mm)		
	μ^{RL}	μ^{SI}	μ^{AP}	Σ^{RL}	Σ^{SI}	Σ^{AP}	σ^{RL}	σ^{SI}	σ^{AP}
VacFix+Bra (MC)	-0.27 [-1; 3.1]	1.35 [-9; 1.5]	-0.46 [-6; 3]	0.79	0.67	1.75	2.60	3.62	3.84
VacFix+Bra (Clavicular)	-0.67 [-4 ; 3.8]	-0.50 [-5 ; 1]	0.28 [-5 ; 3.5]	1.02	0.52	1.25	1.35	1.09	1.94
VacFix+Bra (Axillary)	-0.39 [-5 ; 4]	0.54 [-5 ; 13]	0.85 [-5 ; 6.6]	1.20	1.77	1.65	1.78	2.86	2.47
VacFix+Bra (Breast)	-0.51 [-6.1 ; 4.1]	-0.21 [-11 ; 9.1]	0.53 [-6.3 ; 7.2]	1.32	2.19	0.75	1.95	2.93	1.97
AIO (MC)	-0.15 [-4 ; 1]	0.13 [-4.4 ; 5]	-0.32 [-4 ; 3.1]	0.37	0.45	0.09	0.83	1.33	1.45
AIO(Clavicular)	-1.45 [-7.3 ; 3]	0.03 [-5 ; 5]	0.01 [-6.8 ; 7.9]	1.48	0.72	0.59	1.97	1.47	2.40
AIO (Axillary)	-2.39 [-10.1 ; 4]	-0.23 [-7 ; 5.1]	0.55 [-7.7 ; 7.1]	1.81	0.74	1.16	2.76	1.52	2.44
AIO (Breast)	-0.53 [-8.8 ; 9]	0.47 [-7 ; 10.9]	0.18 [-4.2 ; 5.7]	3.03	1.46	0.94	2.67	2.28	1.70
Thermoplastic Mask (MC)	0.08 [0 ; 1.4]	0.01 [-2.1 ; 2]	0.83 [-2.7 ; 5]	0.18	0.74	0.36	0.25	0.69	1.10
Thermoplastic Mask (Clavicular)	0.15 [-4 ; 5]	-0.62 [-11 ; 3]	1.01 [-2.6 ; 4.1]	1.38	1.54	0.79	1.48	2.04	1.47
Thermoplastic Mask (Axillary)	0.51 [-5 ; 6]	-1.08 [-11 ; 3]	1.89 [-1 ; 5]	1.90	1.93	0.26	1.54	2.43	1.45
Thermoplastic Mask (Breast)	-0.67 [-8.1 ; 6.7]	-1.43 [-7.1 ; 4.1]	2.53 [-4.1 ; 9]	2.18	1.99	1.30	2.57	1.65	2.56
Blue Bag (MC)	-0.15 [-2.6 ; 2]	-0.03 [-3 ; 2.1]	0.68 [-3 ; 5.5]	0.46	0.47	0.38	0.55	0.75	1.37
Blue Bag (Clavicular)	-0.04 [-8.2 ; 4]	-0.49 [-5 ; 3]	0.65 [-4.2 ; 9.1]	1.31	0.71	1.95	1.78	1.26	1.73
Blue Bag (axillary)	0.28 [-4.9 ; 5]	-0.46 [-5 ; 3]	0.88 [-3 ; 9]	1.24	0.73	1.35	1.51	1.25	1.77
Blue Bag (Breast)	0.13 [-5.9 ; 3.9]	-0.71 [-14.3 ; 5]	0.54 [-5 ; 7.2]	0.94	1.02	1.55	1.50	1.51	1.75

Table 3. Rotational global positioning errors resulting from automatic bone registration and manual adjustment

Immobilisation Device	Average systematic errors μ (mm) [range]			Systematic errors SDs Σ (mm)			Average random errors RMS σ (mm)		
	μ^{RL}	μ^{SI}	μ^{AP}	Σ^{RL}	Σ^{SI}	Σ^{AP}	σ^{RL}	σ^{SI}	σ^{AP}
VacFix+Bra (MC)	-0.27 [-3 ; 1.5]	-0.13 [-2.3 ; 1.5]	0.07 [-2 ; 1.7]	0.65	0.39	0.15	0.71	0.74	0.33
VacFix+Bra (Clavicular)	-0.07 [-3 ; 3.5]	-0.09 [-2.3 ; 1.1]	-0.34 [-2 ; 1.7]	1.12	0.40	0.34	0.81	0.65	0.72
VacFix+Bra (Axillary)	-0.14 [-2.3 ; -1.9]	0.12 [-1.9 ; 3]	-0.27 [-2.1 ; 1.7]	1.17	0.64	0.47	0.63	0.75	0.59
VacFix+Bra (Breast)	0.12 [-3.8 ; 3.5]	-0.15 [-5.5 ; 2.4]	-0.22 [-1.8 ; 3]	1.16	1.23	0.51	1.20	1.00	0.83
AIO (MC)	-0.09 [-1.4 ; 1.8]	-0.05 [-1.1 ; 1]	-0.88 [-3 ; 1.8]	0.31	0.14	0.84	0.65	0.42	0.71
AIO(Clavicular)	-0.07 [-1.2 ; 1.8]	0.09 [-2.8 ; 5.1]	-0.85 [-3.1 ; 1.8]	0.27	1.02	0.71	0.64	0.99	0.87
AIO (Axillary)	-0.12 [-1.2 ; 1.5]	0.10 [-2 ; 4]	-0.85 [-3.1 ; 1.8]	0.34	0.67	0.71	0.58	0.94	0.87
AIO (Breast)	-0.01 [-2.8 ; 2.3]	0.58 [-2 ; 3.4]	-0.03 [-2.6 ; 3.2]	0.64	0.72	1.23	0.92	1.16	1.00
Thermoplastic Mask (MC)	-0.22 [-1.8 ; 4.2]	0.23 [-1 ; 2]	0.05 [-1 ; 1.2]	0.69	0.21	0.31	0.85	0.50	0.36
Thermoplastic Mask (Clavicular)	-0.19 [-1.5 ; 4.2]	0.61 [-2 ; 5.9]	0.08 [-1 ; 1.4]	0.67	1.76	0.35	0.83	0.81	0.48
Thermoplastic Mask (Axillary)	-0.22 [-2.5 ; 4.2]	0.46 [-2 ; 5.9]	-0.09 [-2.6 ; 1.4]	0.85	1.67	0.57	0.95	0.96	0.61
Thermoplastic Mask (Breast)	-0.03 [-2.8 ; 4.2]	0.91 [-3 ; 5.9]	-0.05 [-1.6 ; 1.4]	0.91	1.60	0.43	1.32	0.97	0.54
Blue Bag (MC)	-0.27 [-2.3 ; 2]	0.05 [-1.4 ; 1.6]	0.05 [-1.2 ; 1.1]	0.67	0.41	0.52	0.90	0.44	0.40
Blue Bag (Clavicular)	-0.28 [-2.3 ; 2]	-0.41 [-5 ; 1.4]	-0.02 [-2.5 ; 1.1]	0.67	0.51	0.63	0.90	1.08	0.48
Blue Bag (axillary)	-0.24 [-2.3 ; 2]	-0.35 [-3 ; 2]	-0.02 [-2.5 ; 1.1]	0.56	0.44	0.63	0.89	1.00	0.48
Blue Bag (Breast)	-0.14 [-2.3 ; 2.1]	-0.25 [-3.4 ; 4]	-0.02 [-2.5 ; 1.1]	0.51	0.87	0.63	1.12	1.42	0.48

Table 4. Set-up margins

Immobilisation Device	Registration Autobone>manual adjustment			Registration Mammary Chain (MC)			Registration Clavicular nodes			Registration Axillary nodes			Registration Breast + Chest wall		
	RL (mm)	SI (mm)	AP (mm)	RL (mm)	SI (mm)	AP (mm)	RL (mm)	SI (mm)	AP (mm)	RL (mm)	SI (mm)	AP (mm)	RL (mm)	SI (mm)	AP (mm)
VacFix+Bra (MC)	3.8	4.21	7.06	1.82	2.54	2.69	3.80	4.21	7.06	3.80	4.21	7.06	3.80	4.21	7.06
VacFix+Bra (Clavicular)	3.49	2.06	4.49	3.25	3.18	4.33	1.76	2.18	3.43	2.03	6.96	3.96	3.60	7.44	6.12
VacFix+Bra (Axillary)	4.24	6.44	5.86	4.18	6.46	6.17	2.03	6.96	3.96	2.01	2.49	3.16	4.11	7.42	7.33
VacFix+Bra (Breast)	4.67	7.53	3.26	4.46	7.71	4.13	3.60	7.44	6.12	4.11	7.42	7.33	1.56	2.29	2.35
AIO (MC)	1.50	2.05	1.23	1.96	1.98	1.75	5.79	3.55	1.91	6.26	2.56	2.98	8.94	5.48	1.92
AIO(Clavicular)	5.08	2.84	3.15	4.83	2.55	3.11	2.26	2.16	1.49	2.94	1.67	4.28	12.98	6.21	4.53
AIO (Axillary)	6.46	2.90	4.61	6.26	2.56	5.76	2.94	1.67	4.28	2.81	2.15	1.92	14.07	5.92	4.60
AIO (Breast)	9.44	5.24	3.54	8.94	5.48	4.33	12.98	6.21	4.53	14.07	5.92	4.60	2.72	1.67	1.78
Thermoplastic Mask (MC)	0.63	2.32	1.67	1.23	1.54	1.10	4.33	6.87	2.49	5.62	7.86	1.79	7.18	6.00	3.59
Thermoplastic Mask (Clavicular)	4.49	5.28	2.99	4.33	6.87	5.20	1.75	1.43	1.36	7.15	4.25	3.29	6.37	8.98	4.95
Thermoplastic Mask (Axillary)	5.84	6.51	1.65	5.62	7.86	4.03	7.15	4.25	3.29	1.66	1.64	1.25	6.60	8.19	4.58
Thermoplastic Mask (Breast)	7.25	6.12	5.05	7.18	6.00	6.57	6.37	8.98	4.95	6.60	8.19	4.58	2.22	1.57	2.05
Blue Bag (MC)	1.53	1.70	1.91	1.08	1.45	2.20	4.98	2.81	2.47	4.30	2.89	2.02	3.50	3.65	3.67
Blue Bag (Clavicular)	4.52	2.65	6.07	4.98	2.81	5.25	1.59	1.34	2.22	3.78	0.28	2.87	4.09	2.21	7.68
Blue Bag (axillary)	4.16	2.71	4.62	4.30	2.89	4.38	3.78	0.28	2.87	1.48	1.33	2.14	2.16	2.45	6.96
Blue Bag (Breast)	3.39	3.61	5.10	3.50	3.65	6.75	4.09	2.21	7.68	2.12	2.40	6.93	1.47	1.37	2.25