# Comparison of the Pencil Beam Convolution Algorithm and the Analytical Anisotropic Algorithm in Breast Tumors

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## Introduction

The calculation of the dose is one of the key steps in radiotherapy planning[1-5]. This calculation should be as accurate as possible, and over the years it became feasible through the implementation of new algorithms to calculate the dose on the treatment planning systems applied in radiotherapy[1-2,6]. When a breast tumour is irradiated, it is fundamental a precise dose distribution to ensure the planning target volume (PTV) coverage and prevent skin complications[7]. Some investigations, using breast cases, showed that the pencil beam convolution algorithm (PBC) overestimates the dose in the PTV and in the proximal region of the ipsilateral lung. However, underestimates the dose in the distal region of the ipsilateral lung, when compared with analytical anisotropic algorithm (AAA)[8]. With this study we aim to compare the performance in breast tumors of the PBC and AAA algorithms.

## Methodology

The dose calculus was initially done in 40 clinical files using the PBC algorithm in all dosimetric planning of the sample. Subsequently, we proceed to the evaluation of the dose-volume histogram and the dose and percentage of volume within all volumes of interest. Afterwards, the same sample had the dose and percentages calculated with the AAA, using the same procedure mentioned for the PBC algorithm. Data analysis was done with software Statistical Package for Social Sciences version 21.0. The inclusion criteria for the sample were: post lumpectomy female patients with right breast tumours, doing 3DCRT, with 2 to 4 tangential fields, 50Gy of prescribed dose and with an energy of 6MV. It were excluded all patients with lymph nodes invasion and mammary prosthesis. In the PTV it was evaluated the minimum dose, the average dose and the $D_{95\%}$. For the ipsilateral lung, we compared the maximum and average dose and the $V_{10\%}$, $V_{20\%}$ and $V_{30\%}$ for the two algorithms. Finally for the skin it was evaluated the maximum and average dose and the $V_{60\%}$, $V_{80\%}$ and $V_{100\%}$. When outliers were found in the sample it was used the non parametric test Wilcoxon and when we did not find outliers it was used the t test.

## Results and Discussion

In the table 1, we can observed the sample characterization.

Table 1 – Sample Characterization.

| N | Average age | Standart Deviation | Diagnosis | TNM |
|---|---|---|---|---|
| 40 | 57,38 | 11,76 | Invasive Ductal Carcinoma I-II | T1-2N0M0 |

In table 2 it is presented the calculation time of the PBC algorithm and the AAA.

Table 2 – Calculation time between AAA and PBC algorithm.

| | | N | Mean Rank | Sum Rank | Z | Sig. |
|---|---|---|---|---|---|---|
| Calculation Time AAA - Calculation Time PBC | Negative Rank | 4[a] | 3,75 | 15,00 | -5,310 | 0,000 |
| | Positive Rank | 36[b] | 22,36 | 805,00 | | |
| | Ties | 0[c] | | | | |
| | Total | 40 | | | | |

a. Calculation Time AAA < Calculation Time PBC
b. Calculation Time AAA > Calculation Time PBC
c. Calculation Time AAA = Calculation Time PBC

This results are not in agreement with the literature, because Aarup et al. stated that nowadays the differences between calculation time with this algorithms almost not exists[9]. However the PBC algorithm is widely used because it performs the calculation quickly[10]. The table 3 presents the differences in the PTV minimum dose in the two algorithms and the table 4 shows the PTV Maximum, average and D95% in both algorithms.

Table 3 – PTV minimum dose in AAA and PBC algorithm.

| | N | Average | Standat Deviation | t | Freedom Degrees | Sig. |
|---|---|---|---|---|---|---|
| Minimum Dose PBC | 40 | 12,32 | 11,71 | -3,97 | 39 | 0,000 |
| Minimum Dose AAA | 40 | 13,7 | 12,57 | | | |

Table 4 – PTV maximum, average dose and D95% in AAA and PBC algorithm.

| | | N | Mean Rank | Sum Rank | Z | Sig. |
|---|---|---|---|---|---|---|
| Maximum Dose AAA - Maximum Dose PBC | Negative Ranks | 8[a] | 16.63 | 133.00 | -3.723 | 0.000 |
| | Positive Ranks | 32[b] | 21.47 | 687.00 | | |
| | Ties | 0[c] | | | | |
| | Total | 40 | | | | |
| Average Dose AAA - Average Dose PBC | Negative Ranks | 14[d] | 16 | 224 | -2.317 | 0.021 |
| | Positive Ranks | 25[e] | 22.24 | 556 | | |
| | Ties | 1[f] | | | | |
| | Total | 40 | | | | |
| $D_{95\%}$ AAA - $D_{95\%}$ PBC | Negative Ranks | 19[g] | 20.74 | 394 | -0.215 | 0.830 |
| | Positive Ranks | 21[h] | 20.29 | 426 | | |
| | Ties | 0[i] | | | | |
| | Total | 40 | | | | |

a. Maximum Dose AAA < Maximum Dose PBC
b. Maximum Dose AAA > Maximum Dose PBC
c. Maximum Dose AAA = Maximum Dose PBC
d. Average Dose AAA < Average Dose PBC
e. Average Dose AAA > Average Dose PBC
f. Average Dose AAA = Average Dose PBC
g. $D_{95\%}$ AAA < $D_{95\%}$ PBC
h. $D_{95\%}$ AAA > $D_{95\%}$ PBC
i. $D_{95\%}$ AAA = $D_{95\%}$ PBC

Our study shows statistical differences between the two algorithms for the PTV, although, some investigators state that when we want to change the algorithm PBC to AAA, there should be no concerns, regarding the PTV coverage[11]. Other study demonstrates that in breast cases the PTV coverage between the two algorithms is similar[12]. In table 5 we observed the maximum and average doses, $V_{60\%}$, $V_{80\%}$ e $V_{100\%}$ for the skin.

Table 5 - Maximum and average doses, V60%, V80% and V100% for the skin in AAA and PBC algorithm.

| | | N | Mean Ranks | Sum Ranks | Z | Sig. |
|---|---|---|---|---|---|---|
| Average Dose AAA - Average Dose PBC | Negative Ranks | 0[a] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[b] | 20,50 | 820,00 | | |
| | Ties | 0[c] | | | | |
| | Total | 40 | | | | |
| Maximum Dose AAA - Maximum Dose PBC | Negative Ranks | 8[d] | 15,44 | 123,50 | -3,851 | 0,000 |
| | Positive Ranks | 32[e] | 21,77 | 696,50 | | |
| | Ties | 0[f] | | | | |
| | Total | 40 | | | | |
| $V_{60\%}$ AAA - $V_{60\%}$ PBC | Negative Ranks | 0[g] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[h] | 20,50 | 820,00 | | |
| | Ties | 0[i] | | | | |
| | Total | 40 | | | | |
| $V_{80\%}$ AAA - $V_{80\%}$ PBC | Negative Ranks | 0[j] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[k] | 20,50 | 820,00 | | |
| | Ties | 0[l] | | | | |
| | Total | 40 | | | | |
| $V_{100\%}$ AAA - $V_{100\%}$ PBC | Negative Ranks | 5[m] | 10,20 | 51,00 | -4,825 | 0,000 |
| | Positive Ranks | 35[n] | 21,97 | 769,00 | | |
| | Ties | 0[o] | | | | |
| | Total | 40 | | | | |

a. Average Dose AAA < Average Dose PBC
b. Average Dose AAA >Average Dose PBC
c. Average Dose AAA =Average Dose PBC
d. Maximum Dose AAA < Maximum Dose PBC
e. Maximum Dose AAA > Maximum Dose PBC
f. Maximum Dose AAA = Maximum Dose PBC
g. $V_{60\%}$ AAA < $V_{60\%}$ PBC
h. $V_{60\%}$ AAA > $V_{60\%}$ PBC
i. $V_{60\%}$ AAA = $V_{60\%}$ PBC
j. $V_{80\%}$ AAA < $V_{80\%}$ PBC
k. $V_{80\%}$ AAA > $V_{80\%}$ PBC
l. $V_{80\%}$ AAA = $V_{80\%}$ PBC
m. $V_{100\%}$ AAA < $V_{100\%}$ PBC
n. $V_{100\%}$ AAA > $V_{100\%}$ PBC
o. $V_{100\%}$ AAA = $V_{100\%}$ PBC

This results shows that there are statistical differences between the two algorithms for the skin and some authors mentioned that the PBC algorithm underestimates the dose in the build-up region, comparing to the AAA[12]. Finally in table 6 we observed the maximum, average dose and $V_{10\%}$, $V_{20}$% e $V_{30\%}$ for the ipsilateral lung.

Table 6 – Maximum, average doses and $V_{10\%}$, $V_{20}$% e $V_{30\%}$ for the ipsilateral lung in AAA and PBC algorithm.

| | | N | Mean Rank | Sum Ranks | Z | Sig. |
|---|---|---|---|---|---|---|
| Average Dose AAA - Average Dose PBC | Negative Ranks | 0[a] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[b] | 20,50 | 820,00 | | |
| | Ties | 0[c] | | | | |
| | Total | 40 | | | | |
| Maximum Dose AAA - Maximum Dose PBC | Negative Ranks | 37[d] | 21,70 | 803,00 | -5,282 | 0,000 |
| | Positive Ranks | 3[e] | 5,67 | 17,00 | | |
| | Ties | 0[f] | | | | |
| | Total | 40 | | | | |
| $V_{10\%}$ AAA - $V_{10\%}$ PBC | Negative Ranks | 0[g] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[h] | 20,50 | 820,00 | | |
| | Ties | 0[i] | | | | |
| | Total | 40 | | | | |
| $V_{20\%}$ AAA - $V_{20\%}$ PBC | Negative Ranks | 0[j] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[k] | 20,50 | 820,00 | | |
| | Ties | 0[l] | | | | |
| | Total | 40 | | | | |
| $V_{30\%}$ AAA - $V_{30\%}$ PBC | Negative Ranks | 0[m] | 0,00 | 0,00 | -5,511 | 0,000 |
| | Positive Ranks | 40[n] | 20,50 | 820,00 | | |
| | Ties | 0[o] | | | | |
| | Total | 40 | | | | |

a. Average Dose AAA < Average Dose PBC
b. Average Dose AAA > Average Dose PBC
c. Average Dose AAA = Average Dose PBC
d. Maximum Dose AAA < Maximum Dose PBC
e. Maximum Dose AAA > Maximum Dose PBC
f. Maximum Dose AAA = Maximum Dose PBC
g. $V_{10\%}$ AAA < $V_{10\%}$ PBC
h. $V_{10\%}$ AAA > $V_{10\%}$ PBC
i. $V_{10\%}$ AAA = $V_{10\%}$ PBC
j. $V_{20\%}$ AAA < $V_{20\%}$ PBC
k. $V_{20\%}$ AAA > $V_{20\%}$ PBC
l. $V_{20\%}$ AAA = $V_{20\%}$ PBC
m. $V_{30\%}$ AAA < $V_{30\%}$ PBC
n. $V_{30\%}$ AAA > $V_{30\%}$ PBC
o. $V_{30\%}$ AAA = $V_{30\%}$ PBC

Some investigators mentioned that in breast cases there are no differences for the lung doses using PBC algorithm or AAA[11]. However in table 6 we can see that there are statistical differences between the two algorithms for the ipsilateral lung and some authors state that the maximum dose absorbed by the lung is 10% lower when compared to the PBC algorithm[13].

## Final Considerations

Generally, the dose to the PTV calculated by AAA tends to be higher when compared to the PBC algorithm. The AAA also tends to overestimate the dose in the skin and ipsilateral lung, although we only see an overestimation of the PBC algorithm calculated the maximum dose to the ipsilateral lung. In future studies we can make in vivo measurements and compared then with the AAA calculation for breast cases.

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