A new genetic algorithm technique in optimization of permanent ^{125}I prostate implants

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Real time optimized treatment planning at the time of the implant is desirable for ultrasound-guided transperineal ^{125}I permanent prostate implants. Currently available optimization algorithms are too slow to be used in the operating room. The goal of this work is to develop a robust optimization algorithm, which is suitable for such application. Three different genetic algorithms (sGA, sureGA and securGA) were developed and compared in terms of the number of function evaluations and the corresponding fitness. The optimized dose distribution was achieved by searching the best seed distribution through the minimization of a cost function. The cost function included constraints on the periphery dose of the planned target volume, the dose uniformity within the target volume, and the dose to the critical structure. Adjustment between the peripheral dose, the dose uniformity and critical structure dose can be achieved by varying the weighting factors in the cost function. All plans were evaluated in terms of the dose nonuniformity ratio, the conformation number and the dose volume histograms. Among these three GA algorithms, the securGA provided the best performance. Within 2500 function evaluations, the near optimum results were obtained. For a large target volume (5 cm×4 cm×4.5 cm) including urethra with 20 needles, the computer time needed for the optimization was less than 5 min on a HP735 workstation. The results showed that once the best set of parameters was found, they were applicable for all sizes of prostate volume. For a fixed needle geometry, the optimized plan showed much better dose distribution than that of nonoptimized plan. If the critical structure was considered in the optimization, the dose to the critical structure could be minimized. In the cases of irregular and skewed needle geometry, the optimized treatment plans were almost as good as ideal needle geometry. It is concluded that this new genetic algorithm (securGA) allows for an efficient and rapid optimization of dose distribution, which is suitable for real time treatment planning optimization for ultrasound-guided prostate implant. [S0094-2405(98)02412-2]

Key words: brachytherapy, permanent prostate implant, treatment planning, optimization, genetic algorithm

I. INTRODUCTION

An ultrasound-guided transperineal ^{125}I permanent implant technique was first described by Holm *et al.*[1] and later refined by Blasko and Ragde *et al.*[2,3] During this procedure a transrectal ultrasound (TRUS) probe is inserted into the rectum to visualize the prostate and a perineal template is attached as a guide. Needles are then inserted transperineally through the template into the prostate under ultrasound visualization and the radioactive seeds are placed within at predetermined positions.

Prior to the actual implant, computerized dosimetric "pre-planning" is performed which is generally based upon a set of transverse contours obtained a day or two before using computed tomography (CT) or ultrasound imaging. The planned placement of needles and radioactive seeds is guided by classical brachytherapy "rules" (Quimby or Paterson-Parker)[4,5] or published nomograms[6,7] and modified according to the anatomic shapes using a combination of clinical judgement and "trial and error." Since there is a large number of possibilities for arranging the needle and seed positions, it can be very difficult to obtain a good needle and seed arrangement using this manual approach. Tools to assist the pre-planning have been developed using either home-designed codes or codes, which incorporate the existing treatment planning system.[8] Although acceptable dose distributions can be obtained, the numerous manual iterations can require several hours to complete and is highly dependent on the skill and experience of the individual planner.

It has been reported that a least-square optimization method when applied to prostate implants can reduce the pre-planning time by a factor of 10 compared to the manual approach.[9] This substantial improvement clearly indicates the direction to be followed. However, optimization using a local search algorithm, such as least-square fit, may end up in a local minimum[10] and the optimized plan may not be the best plan. For a large configuration space, especially one in which a desired global minimum is hidden among many inferior local minima, an efficient global search strategy must be used. Simulated annealing (SA) and genetic algorithm