Inaccuracy of Thyroid to Background Uptake Ratio in Evaluating Technetium-99m-pertechnetate Thyroid Uptake and Establishing an Improved Algorithm

Changyin Wang, Yanfen Zhao, Ying Shen

Supplementary file 1. The formulae of calculating TcTU.

$$\because \mathrm{TcTU}(\%) = \frac{{}_{\Delta}C_T}{{}_{\Delta}C_I - {}_{\Delta}C_L} \times 100, \text{ and } \quad {}_{\Delta}C_I = {}_{\Delta}C_{pre} - {}_{\Delta}C_{post}$$

$$\therefore \mathrm{TcTU}(\%) = \frac{{}_{\Delta}C_T}{{}_{\Delta}C_{pre} - {}_{\Delta}C_{post} - {}_{\Delta}C_L} \times 100$$

$$\because {}_{\Delta}C_T = {}_{\Delta}t_3^{-1}(C_T - C_{B0})e^{\lambda_{\Delta}t_4}, \quad {}_{\Delta}C_{pre} = kA_1e^{\lambda_{\Delta}t_1}, \quad {}_{\Delta}C_{post} = kA_2e^{\lambda_{\Delta}t_2}, \text{ and } \quad {}_{\Delta}C_L = {}_{\Delta}t_5^{-1}C_me^{\lambda_{\Delta}t_6}$$

$$\therefore \mathrm{TcTU}(\%) = \frac{{}_{\Delta}t_3^{-1}(C_T - C_{B0})e^{\lambda_{\Delta}t_4}}{kA_1e^{\lambda_{\Delta}t_1} - kA_2e^{\lambda_{\Delta}t_2} - {}_{\Delta}t_5^{-1}C_me^{\lambda_{\Delta}t_6}} \times 100$$

$$\because C_{B0} = \frac{C_B}{S_B} \times S_T$$

$$\therefore \mathrm{TcTU}(\%) = \frac{{}_{\Delta}t_3^{-1}(C_TS_B - C_BS_T)e^{\lambda_{\Delta}t_4}}{kS_B(A_1e^{\lambda_{\Delta}t_1} - A_2e^{\lambda_{\Delta}t_2}) - {}_{\Delta}t_5^{-1}S_BC_me^{\lambda_{\Delta}t_6}} \times 100$$

In the above formulae, C is the radioactivity counts in ROI; S is the size of ROI; T is thyroid; B is background. The comments of TcTU, ${}_{\Delta}C_T$, ${}_{\Delta}C_I$, ${}_{\Delta}C_L$, C_T, C_B, C_{B0}, S_T, and S_B are listed in Table 1. C_m is the radioactivity counts in the ROI of injection leakage image, its unit is counts. ${}_{\Delta}C_{pre}$ is the rate of radioactivity counts of the full syringe by attenuation correction before injecting, ${}_{\Delta}C_{post}$ is the rate of radioactivity counts of the empty syringe by attenuation correction after injecting, their units both are counts*min^{-1}. λ is the decay constant of ^{99m}Tc, and λ=0.0019186, its unit is min^{-1}. k is the calibration factor between radioactivity intensity measured with a dose calibrator and radioactivity counts measured with a gamma camera, its unit is counts·min^{-1}·MBq^{-1}. A_1 is the radioactivity intensity of full syringe before injecting, and A_2 is the reliquus radioactivity intensity of empty syringe after injecting, their units both are MBq. The t_0 is the time of measuring the radioactivity intensity of full syringe, ${}_{\Delta}t_1$ is the interval time between the time of finishing the injection and the t_0, ${}_{\Delta}t_2$ is the interval time between the time of measuring the radioactivity intensity of the empty

syringe and the t_0, $_{\Delta}t_3$ is the duration time of thyroid image acquisition, $_{\Delta}t_4$ is the interval time between the time of finishing thyroid image acquisition and the t_0, $_{\Delta}t_5$ is the duration time of image acquisition for injection leakage imaging, and $_{\Delta}t_6$ is the interval time between the time of finishing injection leakage imaging and the t_0, their units all are min.

Supplementary Table 1. Comparison of TcTU between thyroid disease groups and control group.

Group	n	M±IQR	minimum	maximum	Z	P
Control	67	2.22±0.90	0.57	3.57		
Hyperthyroidism	79	14.10±12.68	3.68	39.90	-10.39	0.000
Simple goiter	40	2.85±4.22	1.06	21.98	-2.07	0.038
Subacute thyroiditis	28	0.16±0.16	0.01	0.71	-7.63	0.000
Hypothyroidism	41	0.53±1.87	0.01	38.10	-4.33	0.000
Postoperation of hyperthyroidism	23	1.43±1.70	0.64	3.60	-2.32	0.000
Postoperation of thyroid nodule	44	0.51±0.69	0.03	4.35	-7.01	0.000
Thyroid nodule	48	2.07±0.90	0.52	3.44	-0.93	0.352
Hashimoto's disease	19	3.75±5.73	0.29	30.08	-2.15	0.032

Note: M±IQR, M, median, IQR, inter-quartile range. TcTU, ^{99m}Tc-pertechnetate thyroid uptake rate. Nonparametric test of two independent samples (Type: Mann-Whitney U) was used in comparing the differences of TcTU between different thyroid diseases and control group.

Supplementary Table 2. Comparison of discordance rate and discordance distribution between UR and CUR in different thyroid area sizes.

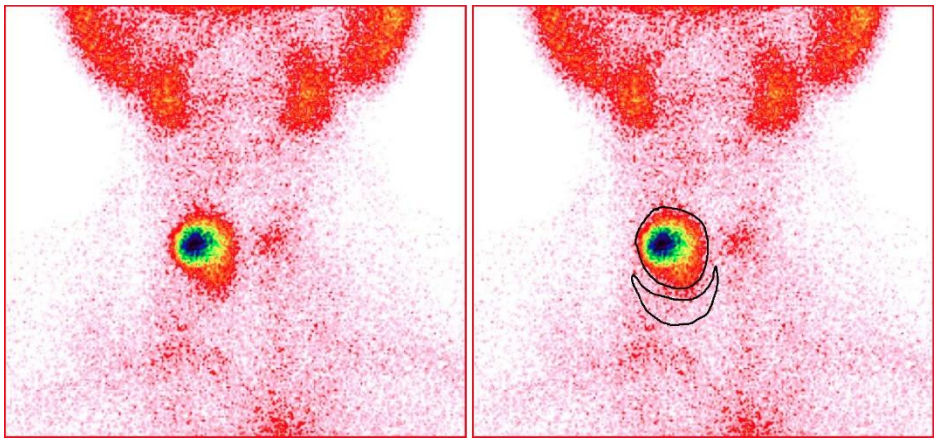
Group		Types of Discordance	Discordance of UR		Discordance of CUR		χ^2	P value
Thyroid size	TcTU		Case number	Rate (%)	Case number	Rate (%)		
	Increased(n=2)	Normal	0	0/2	1	1/2	-	-
Small	Normal(n=29)	Increased	15	51.7	0	0.0	26.1	0.000
(n=90)		Decreased	0	0.0	1	3.4	1.4	0.236
	Decreased(n=59)	Normal	23	39.0	0	0.0	37.5	0.000
	Increased(n=36)	Normal	2	5.6	2	5.6	0.0	1.000
Normal	Normal(n=95)	Increased	1	1.1	1	1.1	0.0	1.000
(n=157)		Decreased	1	1.1	0	0.0	1.4	0.238
	Decreased(n=26)	Normal	5	19.2	5	19.2	0.0	1.000
	Increased(n=83)	Normal	13	15.7	1	1.2	13.2	0.000
Large	Normal(n=50)	Increased	0	0.0	1	2.0	1.4	0.237
(n=142)		Decreased	6	12.0	0	0.0	8.7	0.003
	Decreased(n=9)	Normal or Increased	0	0/9	0	0/9	-	-

Note: TcTU, ^{99m}Tc-pertechnetate thyroid uptake rate; UR, uptake ratio of thyroid-to-background; CUR, corrected UR. Chi-square test was performed in comparing the difference of rates.

Supplementary Table 3. Comparison of S_T between thyroid disease groups and control group.

Group	n	M±IQR	minimum	maximum	Z	P
Control	67	21.85±4.28	16.15	28.97		
Hyperthyroidism	79	32.42±18.60	15.89	68.66	-8.30	0.000
Simple goiter	40	34.23±7.93	23.62	65.78	-8.36	0.000
Subacute thyroiditis	28	8.57±5.34	2.36	30.17	-5.38	0.000
Hypothyroidism	41	25.33±12.35	8.81	78.91	-2.56	0.010
Postoperation of hyperthyroidism	23	10.43±5.27	4.71	39.51	-6.34	0.000
Postoperation of thyroid nodule	44	9.51±5.89	2.04	29.39	-8.28	0.000
Thyroid nodule	48	27.10±13.93	19.48	42.72	-4.32	0.000
Hashimoto's disease	19	24.55±10.12	10.93	36.87	-1.72	0.086

Note: M±IQR, M, median, IQR, inter-quartile range. S_T, thyroid size (cm^2). Nonparametric test of two independent samples (Type: Mann-Whitney U) was used in comparing the differences of S_T between different thyroid diseases and control group.



Supplementary Figure 1. Thyroid imaging and $^{99m}TcO_4^-$ thyroid uptake in a 45-year-old female patient with hypothyroidism after partial thyroidectomy due to multiple nodular goiters.

(Thyroid imaging shows that the remaining thyroid [4.5cm^2] is smaller than normal size [reference range: 16.5-27.6cm^2]. The TcTU was 0.23% [reference range: 0.82-3.52%], presenting decreased $^{99m}TcO_4^-$ uptake; UR was 3.12[reference range: 2.43-6.03], presenting normal $^{99m}TcO_4^-$ uptake; CUR was 1.28[reference range: 2.35-5.99], presenting decreased $^{99m}TcO_4^-$ uptake. The results show that CUR is consistent with TcTU and the state of hypothyroidism, but not with UR.)

TcTU, ^{99m}Tc-pertechnetate thyroid uptake rate; UR, thyroid to background uptake ratio; CUR, corrected thyroid to background uptake ratio.