Original Article

# 방사성 요오드 치료 후, 퇴원 선량 측정에 있어 각국의 기준 및 권고 비교

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# The Study on the Dilution Time of Radioactive Tracer in Estradiol Measurement

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**Purpose** The high-dose administration of I-131 has been standing for the basic therapy method of thyroid cancer. In korea, it is not necessary for patients to be hospitalized if the administration dose are under 1.2 GBq. However, if the dose are over 1.2 GBq, the patients should be stay in special ward with radiation shield. In such cases, the radioactivity level upon release should be under a dose of 70 $\mu$Sv/hr at a distance of approx. 1m. This regulation bring the patients to stay for about 2 to 3 days in ward before the release.

**Materials and Methods** Using the inpatients' release data of severance hospital, an inpatient-days were retrospectively calculated and compared with practical data and estimate the inpatient-days with the conditions of korea (70 $\mu$Sv/hr), Japan (30 $\mu$Sv/hr), germany (3.5 $\mu$Sv/hr at a distance of approx. 2 m), and other european countries.

**Results** When a effective half-life of 15.4 was used, the expected inpatient-days were calculated as 2.15 days in the condition of Japanese regulation and 1.37 days in the condition of korean regulation. The practical inpatient-days of patients in Severance hospital were 1.32 days.

**Conclusion** As ICRP 94 has been mentioned that the release of patients administrated with I-131 for the therapy should be carefully considered because each patients has different thyroid uptake rate and their conditions with family members after the release from the ward. Nonetheless, efforts to bring more aquate data which is for getting closer to the practical data should be continuously studied.

**Key Words** Thyroid iodine therapy, Iodine-131 therapy

## Introduction

Thyroid cancer is rapidly increased cancer all over the world(Table 1).

thyroid cancer incidence has continuously increased in the last three decades all over the world.[1)] This trend is present on every continent. The incidence rate was increased to 13.8% on females in 2000 and 2007 in australia. Italy, its incidence rate was 145% and 127% on females and males, respectively, from 1991 to 1995 and from 2001 to 2005. Japan, 85.7% and 52.4% from 1973 to 1977 and from 1998 to 2002.

The incidence rate of thyroid cancer is steeply increasing compared to the other cancer rate(Fig. 1). The slope degree of t he thyroid cancer rate on female is larger than on male(Fig. 2, 3).

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**Table. 1.** Increase of thyroid cancer incidence rate in different countries. Journal of Cancer Epidemiology.

| Country | Source | Years | | Variation of incidence (APC) | |
|---|---|---|---|---|---|
| | | | | Females | Males |
| Australia | [27] | 1982 | 2007 | — | 4.0 |
| | (*Patients aged 15–30 years*) | 1982 | 2000 | 2.0 | — |
| | | 2000 | 2007 | 13.8 | — |
| Canada | [28] | 1970/72 | 1994/96 | 3.5* | 3.2* |
| | [29] | 2002 | 2008 | 7.3 | 8.4 |
| China (Shanghai) | [30] | 1983 | 2000 | — | 2.6 |
| | | 1983 | 2003 | 4.9 | — |
| Denmark | [2] | 1973/1977 | 1998/2002 | 81.3%‡ | 20.0%‡ |
| Finland | [2] | 1973/1977 | 1998/2002 | 62.8%‡ | 29.4%‡ |
| France | [31] | 1983 | 2000 | 8.98 | 8.13 |
| Israel-Jews | [2] | 1973/1977 | 1998/2002 | 95.2%‡ | 34.6%‡ |
| Italy | [4] | 1991/95 | 2001/05 | 145%‡ | 127%‡ |
| Japan | [2] | 1973/1977 | 1998/2002 | 85.7%‡ | 52.4%‡ |
| Spain | [10] | 1978 | 2001 | 9.4§ | 2.6§ |
| | (*Only PTCs*) | | | | |
| Switzerland | [2] | 1973/1977 | 1998/2002 | 85.7%‡ | 5.3%‡ |
| UK | http://info.cancerresearchuk.org/cancerstats/ | 1993 | 2008 | 2.3 | 0.6 |
| USA | [12] | 1998 | 2005 | 7.0 | 6.3 |
| | http://seer.cancer.gov/statfacts/html/thyro.html | 1997 | 2009 | 7.0 | — |

APC: annual percent change.
*Average annual percent increase.
‡Percent temporal change (% increase) in the indicated period.
§Incidence increase in the indicated period.

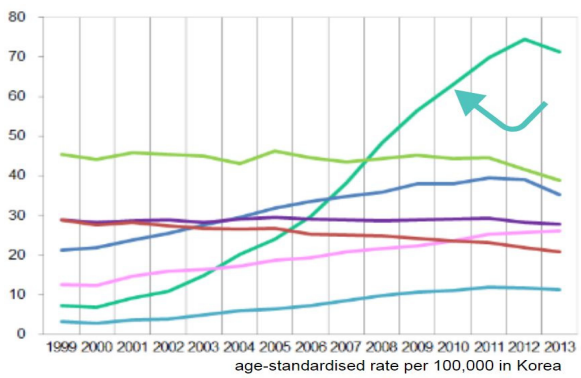


**Fig. 1.** Arrow shows the thyroid cancer rate. Age–standardised rate per 100,000 in Korea, 2013. Korea Central Cancer Registry Cancer Registration & Statistics Branch, Division of Cancer Registration & Surveillance, National Cancer Center, Korea.

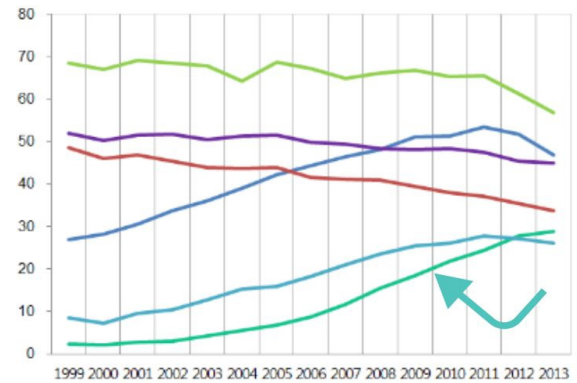


**Fig. 2.** Arrow shows the thyroid cancer rate. Age–standardised rate per 100,000 on male in Korea, 2013. Korea Central Cancer Registry Cancer Registration & Statistics Branch, Division of Cancer Registration & Surveillance, National Cancer Center, Korea.

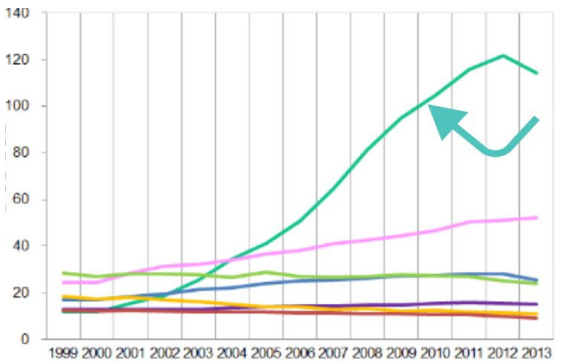


**Fig. 3.** Arrow shows the thyroid cancer rate. Age–standardised rate per 100,000 on female in Korea, 2013. Korea Central Cancer Registry Cancer Registration & Statistics Branch, Division of Cancer Registration & Surveillance, National Cancer Center, Korea.

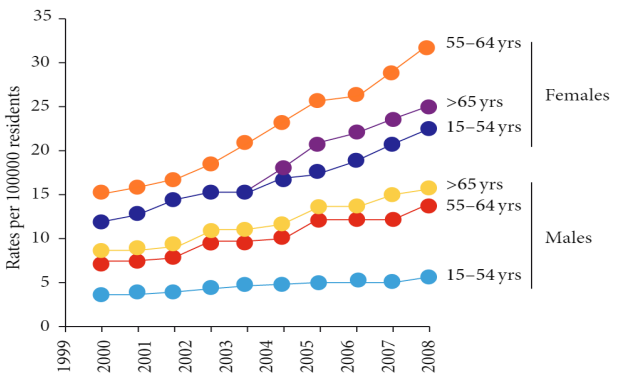


**Fig. 4.** The thyroid cancer incidence is increasing. Worldwide Increasing Incidence of Thyroid Cancer: Update on Epidemiology and Risk Factors, Journal of Cancer Epidemiology, Volume 2013, Article ID 965212, 10 pages, http://dx.doi.org/10.1155/2013/965212

In north america from 1999 to 2008, the thyroid cancer rate has been increased in almost all age groups on females and males(Fig. 4).

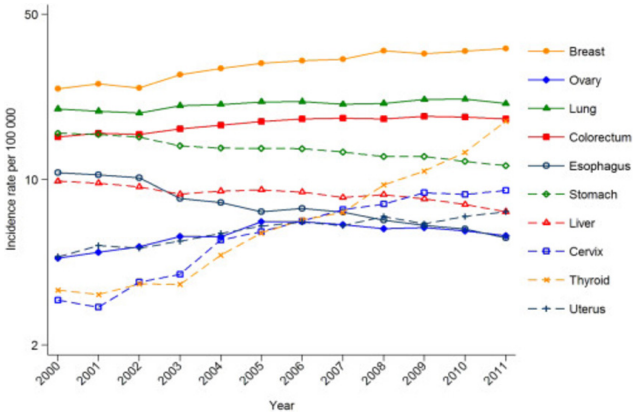


**Fig. 5.** Trends in incidence rates (Age–Standardized to the Segi Standard Population) for selected cancers for females: China, 2000 to 2011.Data source: 22 population–based chinese cancer registries.

Thyroid cancer incidence rate on females is increasing in china(Fig. 5).

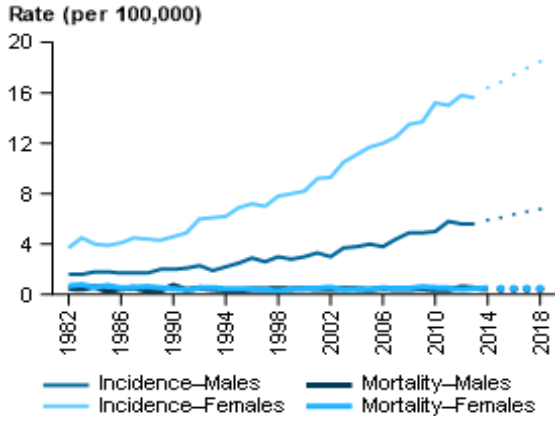


**Fig. 6.** Incidence and mortality ASRs of thyroid cancer, by sex, 1982–2018; Cancer survival and prevalence in Australia: period estimates from 1982 to 2010.

Thyroid cancer incidence rate on females is also increasing in Australia(Fig. 6).

Trends in age-standardized (world population) incidence rates per 100,000 women for thyroid cancer in many countries worldwide have been increasing(Fig. 7, 8). The researchers believes that it's mainly because of the increased exposure to radiation such as CT, and the undiscovered environmental

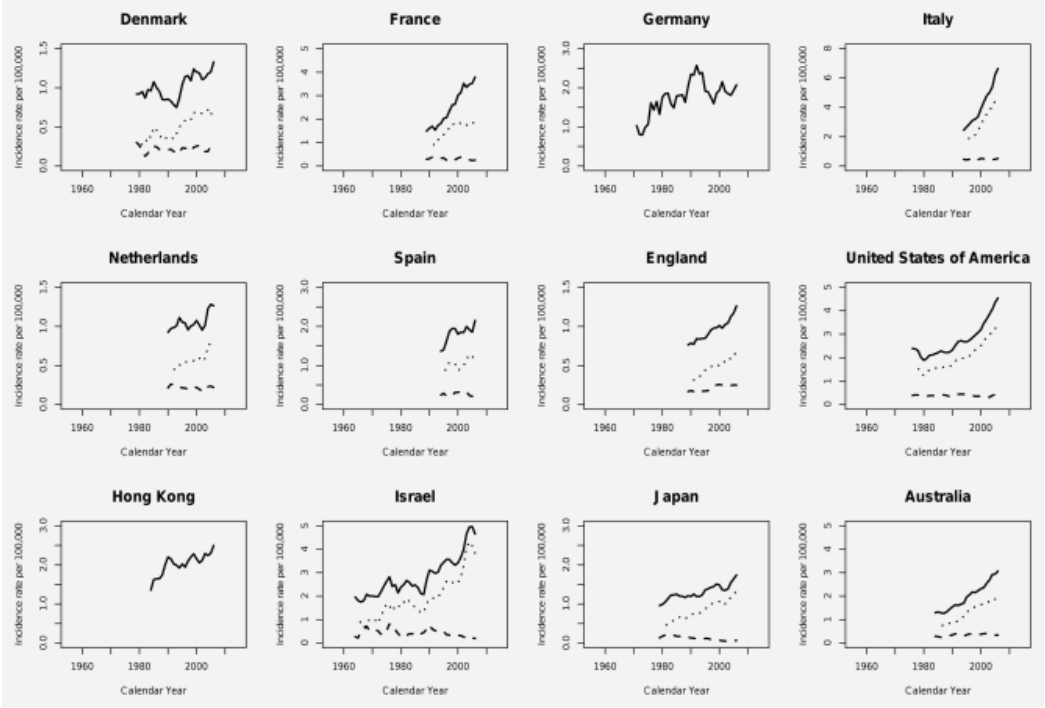


**Fig. 7.** Trends in age–standardized (world population) incidence rates per 100,000 men for thyroid cancer overall and by major histological types in selected countries worldwide, 1960–2007. All thyroid cancers ▬▬; papillary carcinoma ■ ■ ■ ■ and follicular carcinoma ▬ ▬ ▬. International Journal of cancer, Volume 136, Issue 9, 1 May 2015, Pages 2187–219.

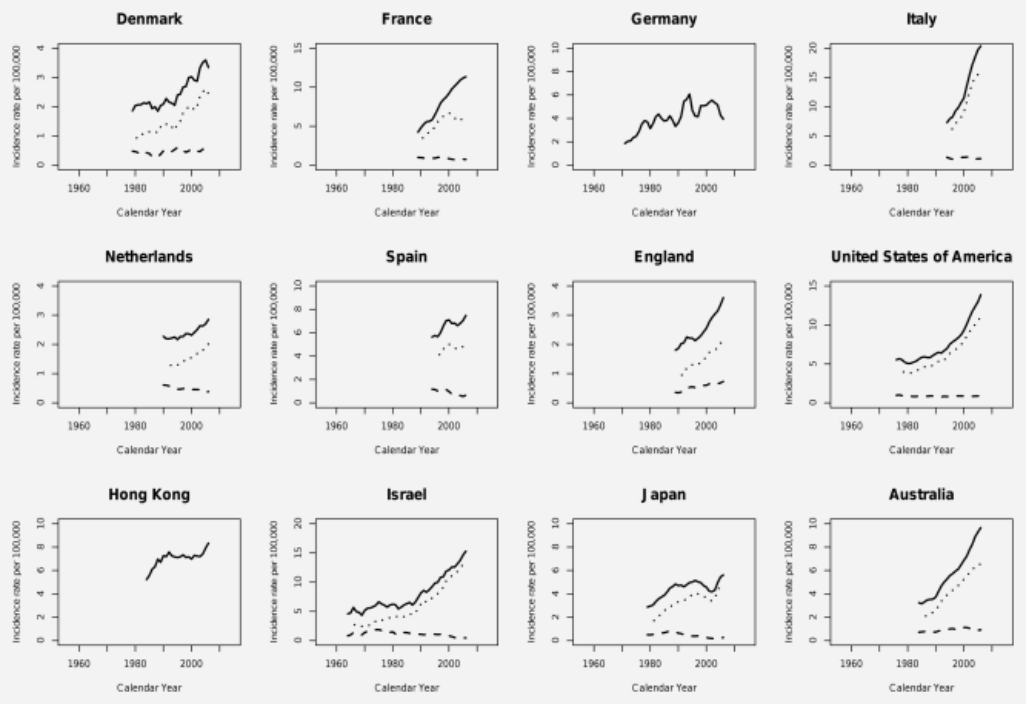


**Fig. 8.** Trends in age–standardized (world population) incidence rates per 100,000 women for thyroid cancer overall and by major histological types in selected countries worldwide, 1960–2007. All thyroid cancers ▬▬; papillary carcinoma ■ ■ ■ ■ ■ and follicular carcinoma ▬ ▬ ▬. International Journal of cancer, Volume 136, Issue 9, 1 May 2015, Pages 2187–219.

carcinogens, for example, an Industrialized life style.[2)]

When people got the thyroid cancer. Simply, they had surgery and iodine therapy in basic routine. Oral administration of I-131 has been a commonly accepted procedure for treatment of the thyroid disease since the 1940s. For the cure of the rest of the malignant thyroid tissue, meaning 'ablation', from 1.1 to 5.55 GBq of I-131 is administered and for the therapy of the metastasis to lymph node, lung, and bone, usually the dose activities were from 5.55 to 7.4 GBq. Because of the high dose gamma ray, the patients who had been dosed with therapeutic activities of I-131 are hospitalized in the specialized facilities such as the isolated room with a lead-shield. And the patients will be discharged from the isolated ward if the activity of radioactive substances in the body falls below 1.2 GBq in korea, and the patient release criteria of korean government 'faithfully' follow NRC's.

NRC is the abbreviation of nuclear regulatory commission which is an independent agency of the united states government tasked with protection public health and safety related to nuclear energy.

Some countries follow the data and recommendations of NRC and some does not. Regulatory requirements for hospitalization and other radiation protection among countries, with many guidelines being more stringent than those of the NRC.

**Table 2.** Activities and dose rates for authorizing patient release; Regulatory Guide 8.39, U.S. Nuclear Regulatory Commision

| | COLUMN 1 ACTIVITY AT OR BELOW WHICH PATIENTS MAY BE RELEASED | | COLUMN 2 DOSE RATE AT 1 METER, AT OR BELOW WHICH PATIENTS MAY BE RELEASED[b] | |
|---|---|---|---|---|
| RADIONUCLIDE | (GBq) | (mCi) | (mSv/hr) | (mrem/hr) |
| Ag-111 | 19 | 520 | 0.08 | 8 |
| Au-198 | 3.5 | 93 | 0.21 | 21 |
| Cr-51 | 4.8 | 130 | 0.02 | 2 |
| Cu-64 | 8.4 | 230 | 0.27 | 27 |
| Cu-67 | 14 | 390 | 0.22 | 22 |
| Ga-67 | 8.7 | 240 | 0.18 | 18 |
| I-123 | 6.0 | 160 | 0.26 | 26 |
| I-125 | 0.25 | 7 | 0.01 | 1 |
| I-125 implant | 0.33 | 9 | 0.01 | 1 |
| I-131 | 1.2 | 33 | 0.07 | 7 |
| In-111 | 2.4 | 64 | 0.2 | 20 |
| Ir-192 implant | 0.074 | 2 | 0.008 | 0.8 |
| P-32 | (c) | (c) | (c) | (c) |
| Pd-103 implant | 1.5 | 40 | 0.03 | 3 |
| Re-186 | 28 | 770 | 0.15 | 15 |
| Re-188 | 29 | 790 | 0.20 | 20 |

Hospitals in korea can release the patients when their dose rate at 1 meter was below 70 $\mu$ Sv/hr, and if the activity is over 1200 MBq he or she will be stay in specific area(Table 2).

**Table 3.** Some national maximum activities for patient release; Safety Reports Series No.63, Release of patients after radionuclide therapy contributions from the with ICRP

| Radionuclide | Retained activity (MBq) | | | | | |
|---|---|---|---|---|---|---|
| | USA | Germany | Sweden | Finland | Japan | Australia |
| | NRC [47], NUREG-1556[68] | [64] | [65] | [71] | [67] | [45] |
| Phosphorus-32 | [a] | | 1200 | | | 1200 |
| Strontium-89 | [a] | | | | 200 | 300 |
| Yttrium-90 | [a] | | 1200 | | 1200 | 4000 |
| Iodine-131 | 1200[b] | 75 | 600 | 800 | 500 | 600 |
| Samarium-153 | 26 000 | | | | | 4000 |

[a] Value not given because of minimal exposure of the public.
[b] Historic value prior to change in approach to that based on 5 mSv. See Annex II.

However, there are variable release criterias among the countries(Table 3). The purpose of present study is to compare the release time followed by I-131 among countries

## MATERIALS AND METHODS

A hundred ninety five patients in severance hospital were subjected. They were administered 50, 100, 120, 150, 200, and 300 mCi of I-131, respectively.

$$D(t) = \frac{34.6\ \Gamma\ Q_0\ T_p\ (1-e^{-0.693t/T_p})}{r^2}$$

Where D(t) = Accumulated exposure at time t, in roentgens,
34.6 = Conversion factor of 24 hrs/day times the total integration of decay (1.44),
$\Gamma$ = Specific gamma ray constant for a point source, R/mCi-hr at 1 cm,
$Q_0$ = Initial activity of the point source in millicuries, at the time of the release,
$T_p$ = Physical half-life in days,
r = Distance from the point source to the point of interest in centimeters,
t = Exposure time in days.

**Fig. 9.** the equation of accumulated exposure at time; Regulatory Guide 8.39, U.S. Nuclear Regulatory Commision.

We modified the equation above to calculate the exposure and dose rate from the patients. The effective half-life was brought from the references as 15.4 ± 4.3 hours and 14 hours.[3-4)]

The release criteria of NRC, dose rate at 1 meter not to exceed 70 $\mu$ Sv/hr, is to set a 'reference value' such as korea. The predicted-isolation time of the patients were simulated with the equation and the effective hale-life.

## RESULTS

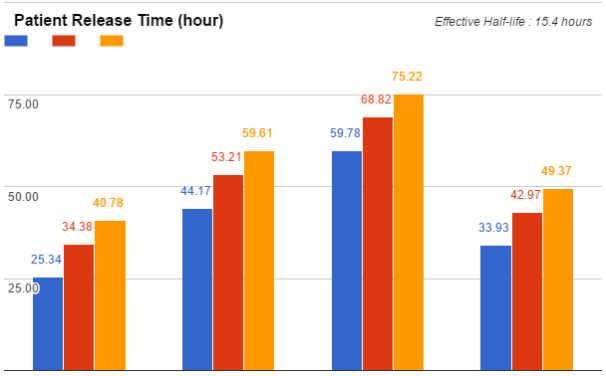


**Fig. 10.** In 15.4 hours of the effective half-life, the predicted-isolated time of the I-131 treated patients with 100, 150, and 200 mCi in korea, japan, germany, and finland.

In korea, if some patients have administered I-131 of 100, 150, and 200 mCi with 15.4 hours of the effective half-life. They should stay in isolated ward to 25.34, 34.38, and 40.78 hours, respectively. And if the patients stay in japan, they have to be isolated for 44.17, 53.21, and 59.61 hours, respectively. In germany, the isolated hours will be 59.78, 68.82, and 75.22. In finland, the isolated hours will be 33.93, 42.97, and 49.37(Fig. 10).

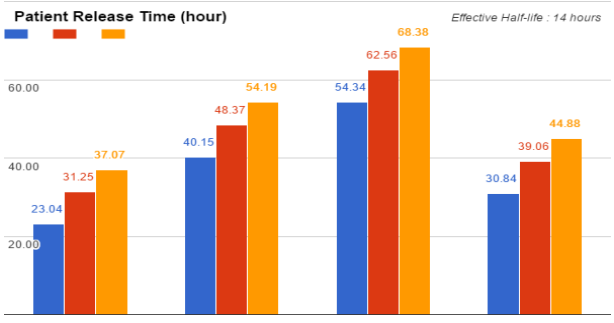


**Fig. 11.** In 14 hours of the effective half-life, the predicted-isolated time of the I-131 treated patients with 100, 150, and 200 mCi in korea, japan, germany, and finland.

In korea, if some patients have administered I-131 of 100, 150, and 200 mCi with 14 hours of the effective half-life. They should stay in isolated ward to 23.04, 31.25, and 37.07 hours,

respectively. And if the patients stay in japan, they have to be isolated for 40.15, 48.37, and 54.19 hours, respectively. In germany, the isolated hours will be 54.34, 62.56, and 68.38. In finland, the isolated hours will be 30.84, 39.06, and 44.88(Fig. 11).

As a results, the patients release criterias of I-131 in japan, germany, and finland could be said to stricter than in korea which follows the NRC's guideline.

## DISCUSSION

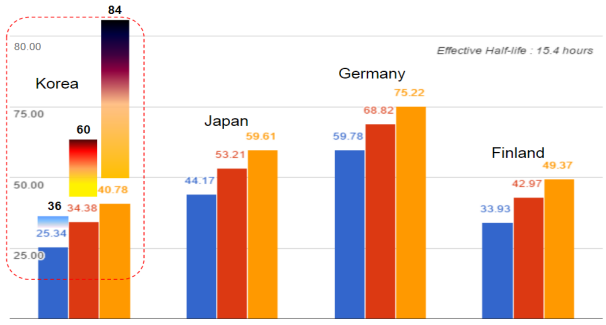


**Fig. 12.** In 15.4 hours of the effective half-life, the predicted-isolated time of the I-131 treated patients with 100, 150, and 200 mCi in korea(extended with maximum staying hours that insurance cover), japan, germany, and finland.

However, in korea, including severance hospital, when patients were administered 100, 150, and 200 mCi. They can be in isolated ward in approximately 1 night 2 days, 2 night 3 days, and 3 night 4 days, respectively. It's not in regulations or by law, but because the insurance can cover the 'in ward days'. In those conditions, the radiation doses from the patients will be much smaller than the criteria when they are released.

## CONCLUSION

As ICRP 94 is mentioned that the release of patients administrated with I-131 for the therapy should be carefully considered because each patients has different thyroid uptake rate and their conditions with family members after the release from the ward. From the present study, the release hours can be varied in each countries. And the ideal hours for release in I-131 treated patients should be needed.

Furthermore, the ideas to reduce the radiation should be started to minimize the radiation to the public, caregiver, and family members. And in terms of that nonetheless, efforts to bring more adequate data which is for getting closer to the pratical data should be continuously studied.

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