방사선: 환자에게 설명하는 TIP


CT 안전해요?
걱정


원자폭탄
원전폭발
방사능
암/기형


나 방사선 피폭 당했어.
오래 살 수 있을까?

최종 목적: 安心 (안심)

무슨 걱정을
그리 하시는지…

무슨 설명을 어떻게
해야 하는지…

정말 안심해도 되나?

검사 끝 났습니다. 안녕히 가세요…

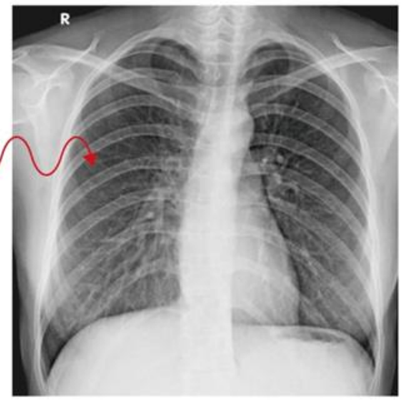
Cancer
Pregnancy
Child

→

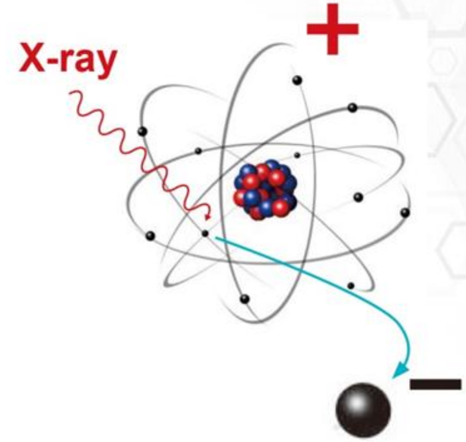
Cancer (Fetus/Child/Adult)
Anomaly (Pregnancy)

근데 왜 ?

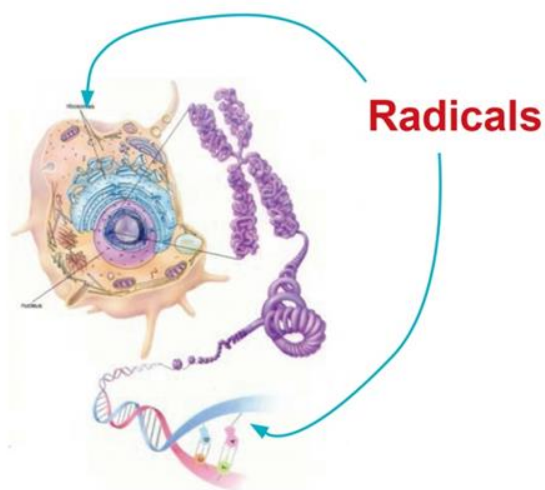
X-ray



Penetration: OK
Attenuation: OMG !!



Photoelectric Effect
: Ionizing Radiation

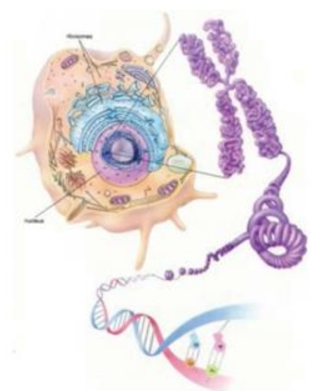


DNA Mutation → Cancer
Cell Death → Anomaly

Radiation Effect
제대로 하는 걱정

과연 !!
진단영역의 저선량 방사선이
Cancer/Anomaly를 발생 ??

Ionizing Radiation → Radicals

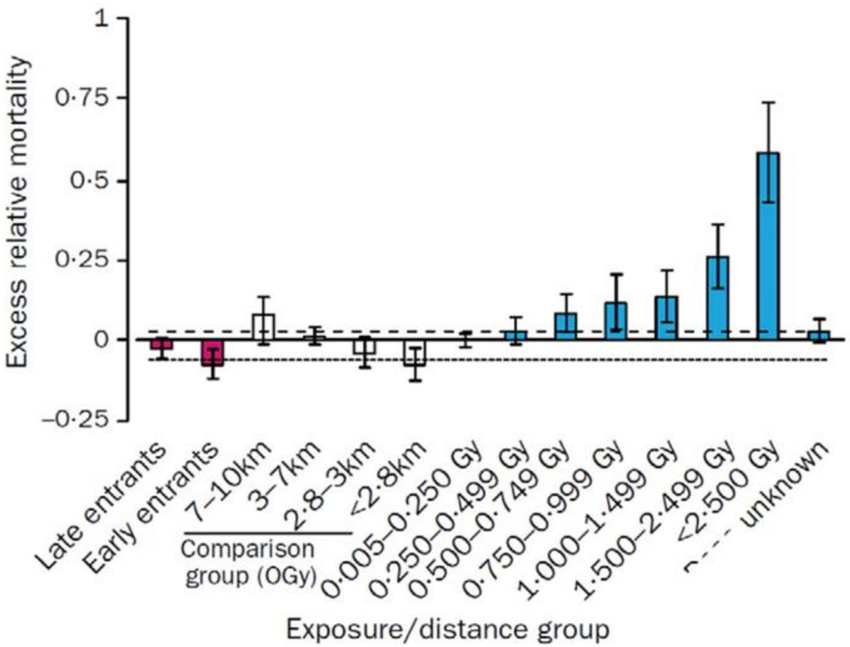


→ **Cancer Anomaly**

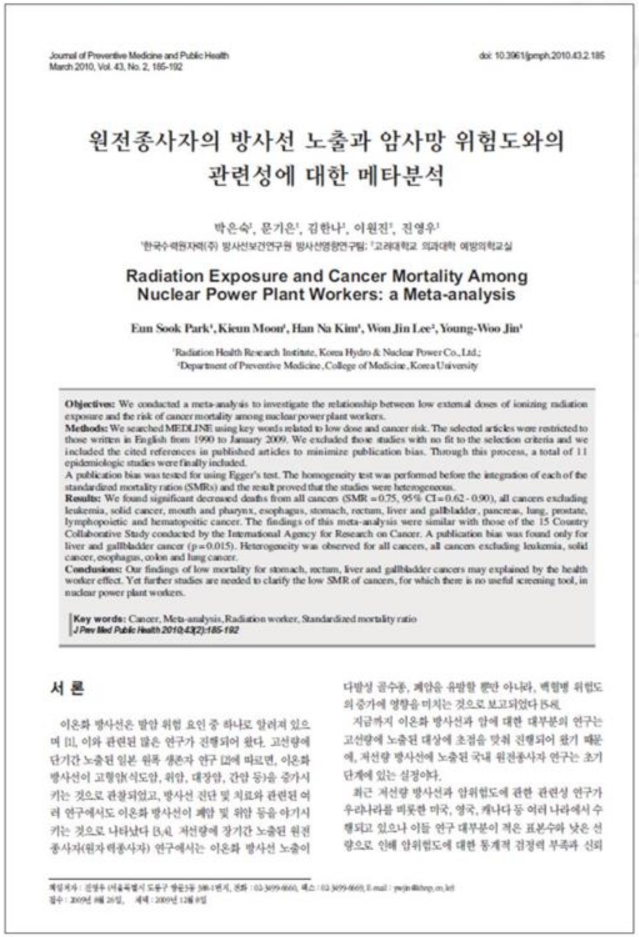
DNA Mutation & Cell Death

Radiation Effect

Longevity of atomic-bomb survivors
Lancet. 2000:303



J Prev Med Public Health. 2010:185


Journal of Preventive Medicine and Public Health
March 2010, Vol. 43, No. 2, 185-192
doi: 10.3961/jpmph.2010.43.2.185

원전종사자의 방사선 노출과 암사망 위험도와의 관련성에 대한 메타분석

박은숙[1], 문기은[1], 김한나[1], 이원진[2], 진영우[1]
[1]한국수력원자력(주) 방사선보건연구원 방사선영향연구팀; [2]고려대학교 의과대학 예방의학교실

Radiation Exposure and Cancer Mortality Among Nuclear Power Plant Workers: a Meta-analysis

Eun Sook Park[1], Kieun Moon[1], Han Na Kim[1], Won Jin Lee[2], Young-Woo Jin[1]
[1]Radiation Health Research Institute, Korea Hydro & Nuclear Power Co., Ltd.;
[2]Department of Preventive Medicine, College of Medicine, Korea University

Objectives: We conducted a meta-analysis to investigate the relationship between low external doses of ionizing radiation exposure and the risk of cancer mortality among nuclear power plant workers.
Methods: We searched MEDLINE using key words related to low dose and cancer risk. The selected articles were restricted to those written in English from 1990 to January 2009. We excluded those studies with no fit to the selection criteria and we included the cited references in published articles to minimize publication bias. Through this process, a total of 11 epidemiologic studies were finally included.
A publication bias was tested for using Egger's test. The homogeneity test was performed before the integration of each of the standardized mortality ratios (SMRs) and the result proved that the studies were heterogeneous.
Results: We found significant decreased deaths from all cancers (SMR = 0.75, 95% CI = 0.62 - 0.90), all cancers excluding leukemia, solid cancer, mouth and pharynx, esophagus, stomach, rectum, liver and gallbladder, pancreas, lung, prostate, lymphopoietic and hematopoitic cancer. The findings of this meta-analysis were similar with those of the 15 Country Collaborative Study conducted by the International Agency for Research on Cancer. A publication bias was found only for liver and gallbladder cancer (p = 0.015). Heterogeneity was observed for all cancers, all cancers excluding leukemia, solid cancer, esophagus, colon and lung cancer.
Conclusions: Our findings of low mortality for stomach, rectum, liver and gallbladder cancers may explained by the health worker effect. Yet further studies are needed to clarify the low SMR of cancers, for which there is no useful screening tool, in nuclear power plant workers.

Key words: Cancer, Meta-analysis, Radiation worker, Standardized mortality ratio
J Prev Med Public Health 2010;43(2):185-192

서 론

이온화 방사선은 발암 위험 요인 중 하나로 알려져 있으며 [1], 이와 관련된 많은 연구가 진행되어 왔다. 고선량에 단기간 노출된 일본 원폭 생존자 연구 [2]에 따르면, 이온화 방사선이 고형암(식도암, 위암, 대장암, 간암 등)을 증가시키는 것으로 관찰되었고, 방사선 진단 및 치료와 관련된 여러 연구에서도 이온화 방사선이 폐암 및 위암 등을 야기시키는 것으로 나타났다 [3,4]. 저선량에 장기간 노출된 원전종사자(원자력종사자) 연구에서는 이온화 방사선 노출이 다발성 골수종, 폐암을 유발할 뿐만 아니라, 백혈병 위험도의 증가에 영향을 미치는 것으로 보고되었다 [5-8].

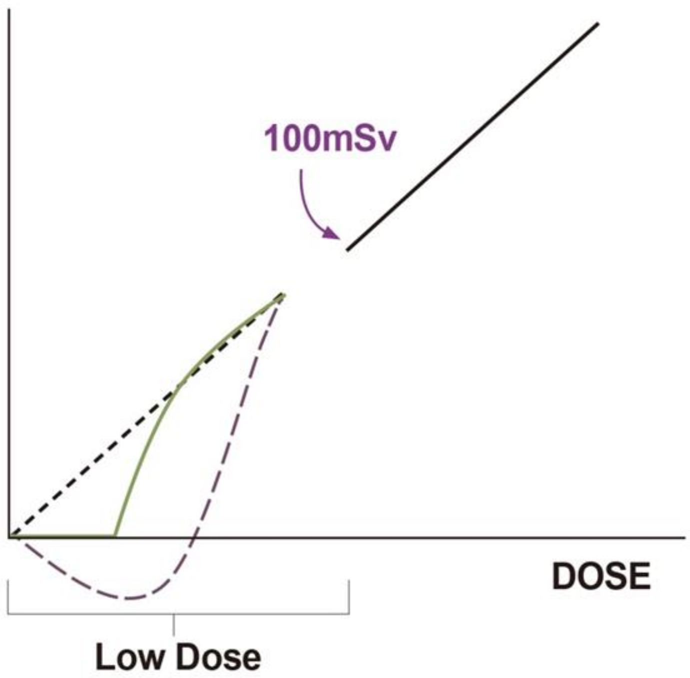
지금까지 이온화 방사선과 암에 대한 대부분의 연구는 고선량에 노출된 대상에 초점을 맞춰 진행되어 왔기 때문에, 저선량 방사선에 노출된 국내 원전종사자 연구는 초기 단계에 있는 실정이다.

최근 저선량 방사선과 암위험도에 관한 관련성 연구가 우리나라를 비롯한 미국, 영국, 캐나다 등 여러 나라에서 수행되고 있으나 이들 연구 대부분이 적은 표본수와 낮은 선량으로 인해 암위험도에 대한 통계적 검정력 부족과 신뢰

생물학적 긍정효과 (Hormesis Effect) ?
건강근로자효과 (Healthy Worker Effect) ?

원전종사자 표준화 사망비: 0.80 (p<0.001)
→ 암 사망률: 원전종사자 < 일반인

Radiation Effect



Linear No Threshold (LNT)

Linear Threshold

Hormesis

> Excess risk of cancer induction d/t Radiation
> - 1000 mSv — 1000 persons
> - 100 mSv — 100,000 persons
> - 10 mSv — 10,000,000 persons

Radiographics. 2008,1807

> 10 mGy:
> Spontaneous transformation ↓
> In culture cells

Science. 2003,378

Radiation Effect

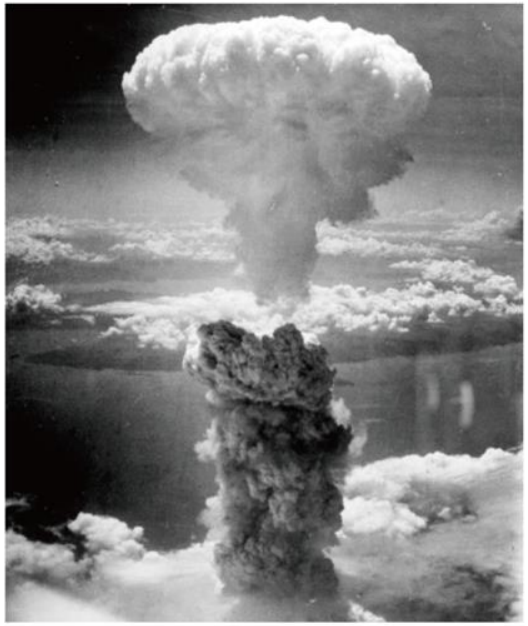
①

Radiation Dose from single CT scan
→ Effect을 입증하기 어려울 정도의 Low Rad..

But, Linear no threshold model
→ Cancer risk는 여전히…

Pregnancy

나 임신 5주 !!
근데 CT 찍었어
애기 기형 ??
낙태 해야 해요?



2800 pregnancy
> 10 mGy — 500

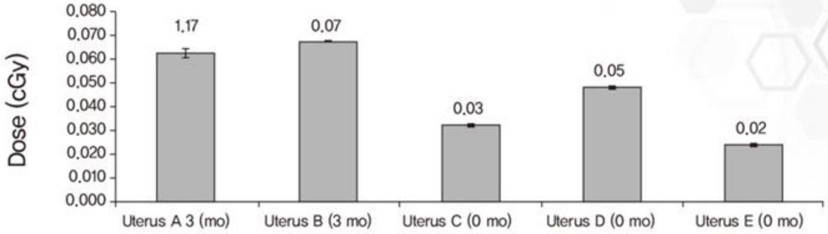
Prenatal Death
IUGR 200 mGy
Small head size
Severe MR 100 mGy
Reduced IQ 100 mGy
Organ Malformation 250 mGy
Childhood cancer

Gestation Age
Repair Mechanism
Absorbed Radiation Dose

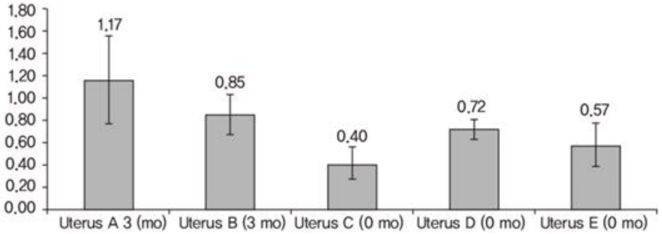
CT 찍어서 Conceptus가 받는
흡수선량은 어느 정도 인가요?

Pregnancy

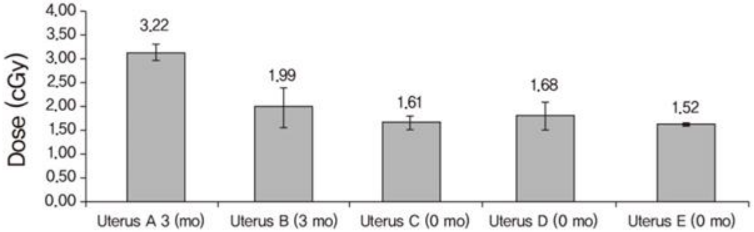
Parameter	Chest CT for Pulmonary Embolus	Appendix CT	Renal Stone CT
Peak kilovoltage (kVp)	140	140	140
Tube current (mA)	380	340	160
Collimation (mm)	1.25	0.625	0.625
Number of slices	158	77	66
Tube rotation (sec)	0.8	0.5	0.5
Total time (sec)	5.3	11.5	9.9
Pitch	1.375:1	1.75:1	1.75:1
$CTDI_{vol}$ (mGy)	28.39	15.47	6.63
DLP (mGy × cm)	507.3	670.82	229.75
	140 kVp 211 e-mAs 8.6 mSv	**140 kVp 97 e-mAs 11.4 mSv**	**140 kVp 45 e-mAs 3.9 mSv**



Pulmonary CTA
Embryo 0.24-0.47 mGy
Fetus 0.61-0.66 mGy



Appendix CT
Embryo 15.2-16.8 mGy
Fetus 19.9-32.2 mGy



Renal Stone CT
Embryo 4.0-7.2 mGy
Fetus 8.5-11.7 mGy

Pregnancy

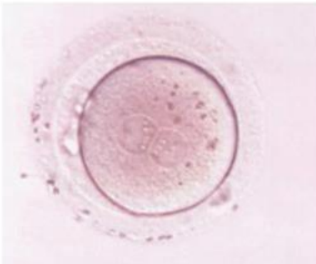
Examination	Typical Conceptus Dose (mGy)
Cervical spine (AP, lat)	<0.001
Extremities	<0.001
Chest (PA, lat)	0.002
Thoracic spine (AP, lat)	0.003
Abdomen (AP)	
21-cm patient thickness	1
33-cm patient thickness	3
Lumbar spine (AP, lat)	1
Limited IVP*	6
Small-bowel study†	7
Double-contrast barium enema study‡	7

Examination	Dose Level	Typical Conceptus Dose (mGy)
Extra-abdominal		
Head CT	Standard	0
Chest CT		
Routine	Standard	0.2
Pulmonary embolus	Standard	0.2
CT angiography of coronary arteries	Standard	0.1
Abdominal		
Abdomen, routine	Standard	4
Abdomen/pelvis, routine	Standard	25
CT angiography of aorta (chest through pelvis)	Standard	34
Abdomen/pelvis, stone protocol*	Reduced	10

Examination	Typical Conceptus Dose (mGy)	
	Early First Trimester	End of First Trimester
Bone scan	5	4
Whole-body PET scan	15	10
Thyroid scan	0.2	0.1

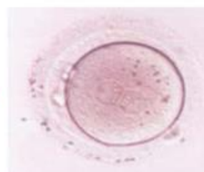
Max 34 mGy → Anomaly ??

Pregnancy



3주 8주 25주

Organogenesis CNS Development



Anomaly

Metal Retardation

확정적 (Deterministic)

Malformation (3–8 wks.): Threshold Dose 100–200 mGy
Brain Damage (8–25 wks.): Threshold Dose 200 mGy

IQ Reduction

- < 100 mGy: No
- 1000 mGy (8–15 wks.): IQ 30 ↓

: Mental retardation 40% (vs. natural 3%)

Pregnancy

- **National Council on Radiation Protection and Measurements (NCRP)**
  "The risk of abnormality is considered to be negligible at 50 mGy or less when compared to other risks of pregnancy, and the risk of malformations is significantly increased above control levels only at doses above 150 mGy. Therefore, exposure of the fetus to radiation arising from diagnostic procedures would very rarely be cause, by itself, for terminating a pregnancy."

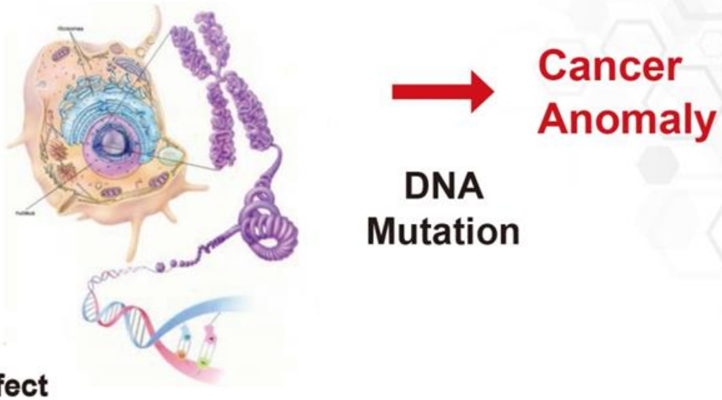
- **American College of Radiology (ACR)**
  "The interruption of pregnancy is rarely justified because of radiation risk to the embryo or fetus from a radiologic examination."

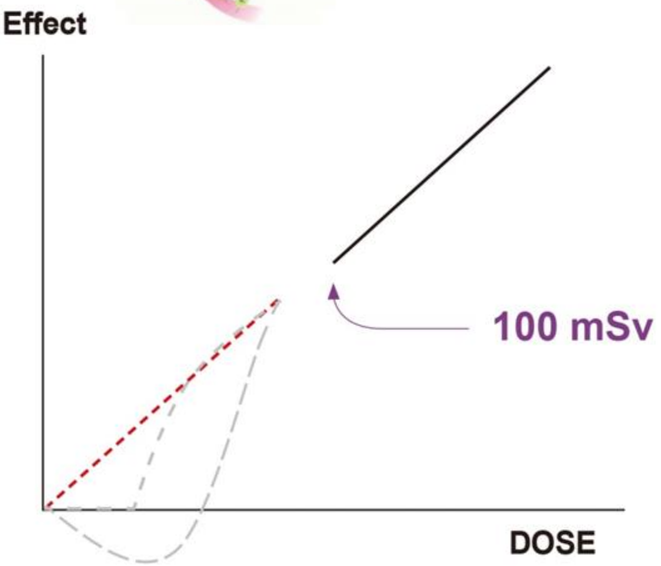
- **International Commission on Radiological Protection (ICRP)**
  "Prenatal doses from most properly done diagnostic procedures present no measurably increased risk of prenatal death, malformation, or impairment of mental development over the background incidence of these entities."

- **American College of Obstetricians and Gynecologists (ACOG)**
  "Fetal doses below 100 mGy should not be considered a reason for terminating a pregnancy." "Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 50 mGy has not been associated with an increase in fetal anomalies or pregnancy loss. "

② No termination

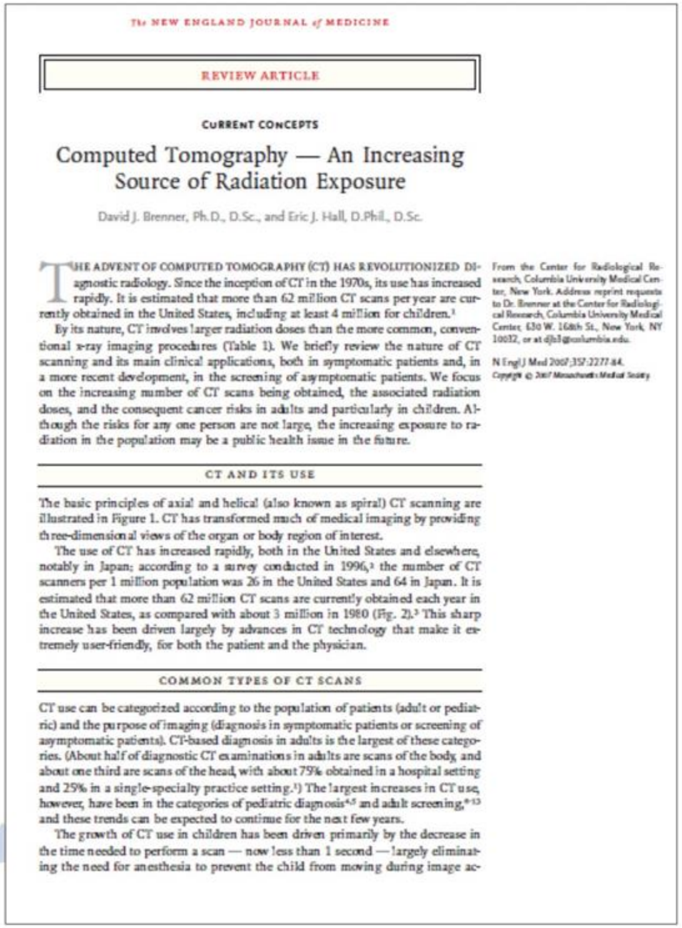
Cancer





Linear No Threshold (LNT)

Cancer



The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

CURRENT CONCEPTS

Computed Tomography — An Increasing Source of Radiation Exposure

David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc.

THE ADVENT OF COMPUTED TOMOGRAPHY (CT) HAS REVOLUTIONIZED DIagnostic radiology. Since the inception of CT in the 1970s, its use has increased rapidly. It is estimated that more than 62 million CT scans per year are currently obtained in the United States, including at least 4 million for children.[1]

By its nature, CT involves larger radiation doses than the more common, conventional x-ray imaging procedures (Table 1). We briefly review the nature of CT scanning and its main clinical applications, both in symptomatic patients and, in a more recent development, in the screening of asymptomatic patients. We focus on the increasing number of CT scans being obtained, the associated radiation doses, and the consequent cancer risks in adults and particularly in children. Although the risks for any one person are not large, the increasing exposure to radiation in the population may be a public health issue in the future.

From the Center for Radiological Research, Columbia University Medical Center, New York. Address reprint requests to Dr. Brenner at the Center for Radiological Research, Columbia University Medical Center, 630 W. 168th St., New York, NY 10032, or at djb3@columbia.edu.

N Engl J Med 2007;357:2277-84.
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CT AND ITS USE

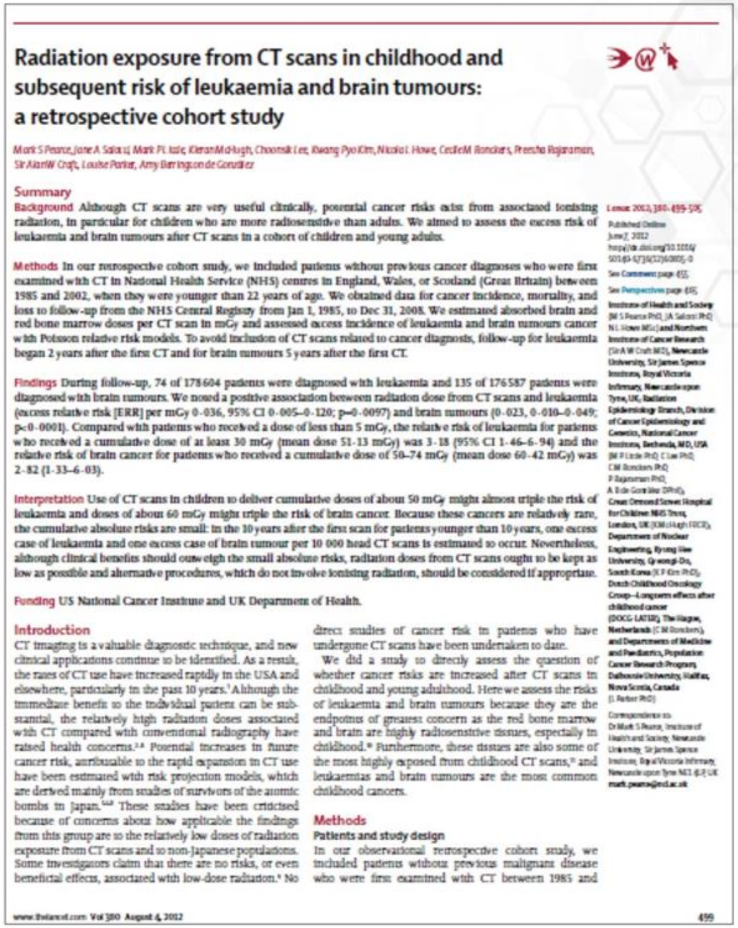
The basic principles of axial and helical (also known as spiral) CT scanning are illustrated in Figure 1. CT has transformed much of medical imaging by providing three-dimensional views of the organ or body region of interest.

The use of CT has increased rapidly, both in the United States and elsewhere, notably in Japan; according to a survey conducted in 1996,[2] the number of CT scanners per 1 million population was 26 in the United States and 64 in Japan. It is estimated that more than 62 million CT scans are currently obtained each year in the United States, as compared with about 3 million in 1980 (Fig. 2).[3] This sharp increase has been driven largely by advances in CT technology that make it extremely user-friendly, for both the patient and the physician.

COMMON TYPES OF CT SCANS

CT use can be categorized according to the population of patients (adult or pediatric) and the purpose of imaging (diagnosis in symptomatic patients or screening of asymptomatic patients). CT-based diagnosis in adults is the largest of these categories. (About half of diagnostic CT examinations in adults are scans of the body, and about one third are scans of the head, with about 75% obtained in a hospital setting and 25% in a single-specialty practice setting.[3]) The largest increases in CT use, however, have been in the categories of pediatric diagnosis[4,5] and adult screening,[6-13] and these trends can be expected to continue for the next few years.

The growth of CT use in children has been driven primarily by the decrease in the time needed to perform a scan — now less than 1 second — largely eliminating the need for anesthesia to prevent the child from moving during image ac-



Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce, Jane A Salotti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de González

Summary

Background Although CT scans are very useful clinically, potential cancer risks exist from associated ionising radiation, in particular for children who are more radiosensitive than adults. We aimed to assess the excess risk of leukaemia and brain tumours after CT scans in a cohort of children and young adults.

Methods In our retrospective cohort study, we included patients without previous cancer diagnoses who were first examined with CT in National Health Service (NHS) centres in England, Wales, or Scotland (Great Britain) between 1985 and 2002, when they were younger than 22 years of age. We obtained data for cancer incidence, mortality, and loss to follow-up from the NHS Central Registry from Jan 1, 1985, to Dec 31, 2008. We estimated absorbed brain and red bone marrow doses per CT scan in mGy and assessed excess incidence of leukaemia and brain tumours cancer with Poisson relative risk models. To avoid inclusion of CT scans related to cancer diagnosis, follow-up for leukaemia began 2 years after the first CT and for brain tumours 5 years after the first CT.

Findings During follow-up, 74 of 178 604 patients were diagnosed with leukaemia and 135 of 176 587 patients were diagnosed with brain tumours. We noted a positive association between radiation dose from CT scans and leukaemia (excess relative risk [ERR] per mGy 0·036, 95% CI 0·005–0·120; p=0·0097) and brain tumours (0·023, 0·010–0·049; p<0·0001). Compared with patients who received a dose of less than 5 mGy, the relative risk of leukaemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51·13 mGy) was 3·18 (95% CI 1·46–6·94) and the relative risk of brain cancer for patients who received a cumulative dose of 50–74 mGy (mean dose 60·42 mGy) was 2·82 (1·33–6·03).

Interpretation Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer. Because these cancers are relatively rare, the cumulative absolute risks are small: in the 10 years after the first scan for patients younger than 10 years, one excess case of leukaemia and one excess case of brain tumour per 10 000 head CT scans is estimated to occur. Nevertheless, although clinical benefits should outweigh the small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionising radiation, should be considered if appropriate.

Funding US National Cancer Institute and UK Department of Health.

Published Online June 7, 2012

Introduction

CT imaging is a valuable diagnostic technique, and new clinical applications continue to be identified. As a result, the rates of CT use have increased rapidly in the USA and elsewhere, particularly in the past 10 years.[1] Although the immediate benefit to the individual patient can be substantial, the relatively high radiation doses associated with CT compared with conventional radiography have raised health concerns.[2-8] Potential increases in future cancer risk, attributable to the rapid expansion in CT use have been estimated with risk projection models, which are derived mainly from studies of survivors of the atomic bombs in Japan.[5,6,9] These studies have been criticised because of concerns about how applicable the findings from this group are to the relatively low doses of radiation exposure from CT scans and to non-Japanese populations. Some investigators claim that there are no risks, or even beneficial effects, associated with low-dose radiation.[9] No direct studies of cancer risk in patients who have undergone CT scans have been undertaken to date.

We did a study to directly assess the question of whether cancer risks are increased after CT scans in childhood and young adulthood. Here we assess the risks of leukaemia and brain tumours because they are the endpoints of greatest concern as the red bone marrow and brain are highly radiosensitive tissues, especially in childhood.[8] Furthermore, these tissues are also some of the most highly exposed from childhood CT scans,[11] and leukaemias and brain tumours are the most common childhood cancers.

Methods

Patients and study design

In our observational retrospective cohort study, we included patients without previous malignant disease who were first examined with CT between 1985 and

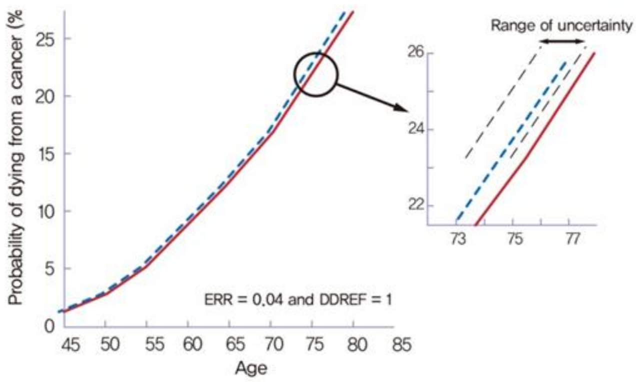
www.thelancet.com Vol 380 August 4, 2012 499

NEJM. 2007,2277 Atomic Bomb
1.5-2.0% of Cancer Mortality: CT

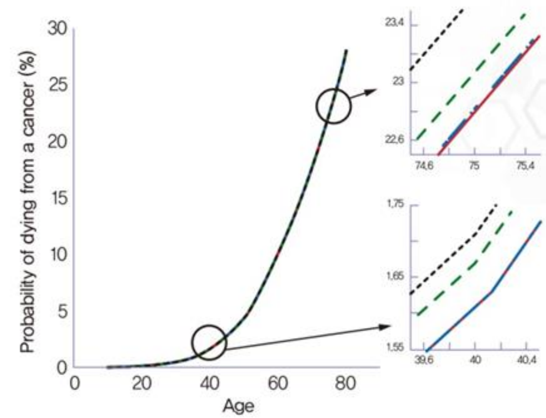
Lancet. 2012,499 Cohort Study
- **Leukemia ERR 0.036/mGy — 50 mGy x3**
- **Brain Tumor ERR 0.023/mGy — 60 mGy x3**

Cancer

Radiographics. 2008,1807



40 y @ 100mSv



5 y @ 1, 10, 30mSv

③

암이 생기는 것이 아니라,
암 발생 확률이 조금 높아지는 구나. 인정
하지만. 검사는 꼭 필요하니까.
너무 예민할 필요는…

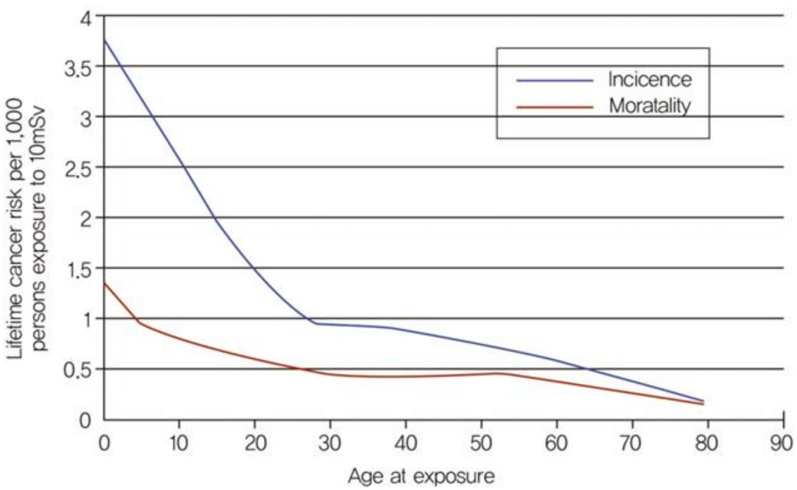
What to Tell Your Patients concerning Additional Risk of Death from Cancer

Effective Dose (mSv)	Risk	Quantification	Examination
<0.1	$<10^{-6}$	Negligible	Radiography of the chest (postero-anterior), extremities, or teeth
0.1–1.0	10^{-5}	Minimal or extremely low	Abdomen, lumbar spine
1.0–10	10^{-4}	Very low	CT of the brain, chest, or abdomen
10–100	10^{-3}	Low	Multiphase CT
>100	$>10^{-2}$	Moderate	Interventional procedures,* repeat CT

← 3200 km Driving

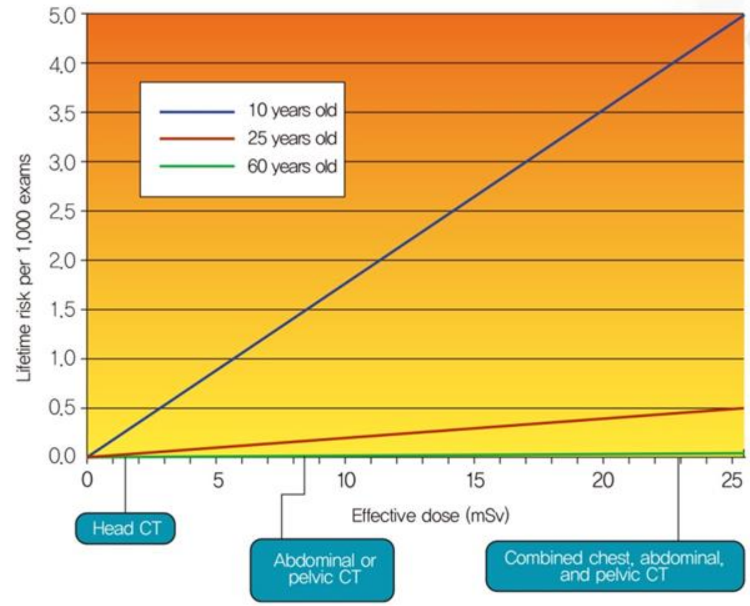
Child

Lifetime Cancer Risk–Incidence and Mortality from a Single CT Scan



10 mSv CT scan
BEIR 2005

Lifetime Risk of Developing Cancer



Picano 2004

Child

Table 2
Probability of Birth with No Malformation and No Childhood Cancer

Dose to Conceptus (mGy)	No Malformation (%)	No Childhood Cancer (%)	No Malformation and No Childhood Cancer (%)
0	96.00	99.93	95.93
0.5	95.999	99.926	95.928
1.0	95.998	99.921	95.922
2.5	95.995	99.908	95.91
5.0	95.99	99.89	95.88
10.0	95.98	99.84	95.83
50.0	95.90	99.51	95.43
100.0	95.80	99.07	94.91

④ The absolute risks of fetal effects, including childhood cancer induction, are small at conceptus doses of 100 mGy and negligible at doses of less than 50 mGy.

Conclusions

① Effect of Low Dose Radiation & LNT

② No termination

③ Probability ↑ of Cancer Mortality, But very low…

④ The childhood cancer induction is negligible at doses of less than 50 mGy.

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Thanks to first-year resident doctors from Gangnam Severance Hospital