Chapter 5

An Observational Study of Pigs Exposed to Radiation

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Abstract On June 28, 2011, 26 pigs were rescued from the alert area, 17 km northwest of the [Fukushima Daiichi Nuclear Power Plant](#), where radiation levels were approximately 1.9–3.8 $\mu\text{Sv/h}$. The pigs were transferred outside of the radiation alert area to the Animal Resource Science Center (ARSC), The University of Tokyo. It was confirmed by the farm owner that the pigs were never fed radiation-contaminated concentrate and they had access to uncontaminated groundwater (<http://www.env.go.jp/press/press.php?serial=16323>) while living inside the radiation alert area; however, radiocesium was detected in the rescued pigs' organs, testis/ovary, spleen, liver, kidney, psoas major, urine, and blood, within nine months after the nuclear disaster. Radiocesium levels in samples collected in early January 2012 were significantly lower than those collected in either early or late September 2011, indicating a continuing decrease in radiation levels over that duration. Radiocesium was not detected in organs collected in August 2012. In September 2011, the authors of the present study visited a local farm to collect samples from pigs who remained inside the radiation alert area. Radiocesium concentration in these pigs was nearly ten times higher than from the rescued pigs.

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Seven of the 16 sows rescued were able to reproduce. The present study showed that the age of sow significantly affected their ability to reproduce. These 7 sows had 15 parturition events and birthed 166 piglets, including two malformed piglets. However, the present study confirmed that body weight did not affect reproductive performance. The average body weight of reproductive and non-reproductive sows was 226.3 versus 230.6 kg, respectively.

Hematology analysis showed that red blood cells (RBC) were lower in rescued pigs than in the non-exposed pigs. The level of HGB, HCT, MCV, and MCH, which are all related to RBC counts, were consistent with the changes in RBC between the two groups. The plasma biochemical indexes that relate to liver and kidney functions also showed differences between the two groups of pigs.

The present study was not scientifically designed and did not contain proper control groups for all tests. As a result, we are not able to conclude the exact effects of the radiation exposure to the pigs' health.

Keywords Radiation · Pig · Reproduction · Malformation · Radiocesium · Fukushima Daiichi Nuclear Power Plant Accident

5.1 Introduction

On March 11, 2011, a magnitude 9.1 earthquake occurred off the Pacific coast of Tohoku, Japan. The earthquake triggered a powerful tsunami wave that destroyed local villages and took a tremendous toll on human life. The earthquake and subsequent tsunami also led to the [Fukushima Daiichi Nuclear Power Plant](https://www.fukushima-npp.com/en/) disaster. This accident resulted in a nuclear reactor meltdown followed by the release of radioactive fallout. Residents were evacuated within a 20-km radius of the Fukushima Daiichi Nuclear Power Plant. On June 28, 2011, 26 pigs were rescued from an area 17 km northwest of the Fukushima Daiichi Nuclear Power Plant and transported outside of the alert zone to the ARSC of the University of Tokyo, located 140 km southwest of the Fukushima Daiichi Nuclear Power Plant. The pigs had remained in the alert zone for 107 days with radiation levels measuring approximately 1.9–3.8 $\mu\text{Sv/h}$ (https://ramap.jmc.or.jp/map/#lat=37.551093857523306&lon=140.96295470535136&z=15&b=std&t=air&s=25,0,0,0&c=20110429_dr). Details of the rescued pigs are listed in Table 5.1.

After the rescued pigs arrived at ARSC, they were given two restricted feedings per day; this is the same diet fed to the reproductive pigs already housed at the ARSC. Body weights were measured once a month. Tests of groundwater and feed confirmed that neither were contaminated by radioactive material. However, two months after the pigs' arrival at ARSC, the health of some pigs deteriorated, and radiocesium was detected in samples taken from the pigs' organs, testis/ovary, spleen, liver, kidney, psoas major, urine, and blood.

The present study was conducted to evaluate bodyweight changes, lifespan and reproductive performance of the rescued pigs. In addition, an observationally based

Table 5.1 List of the rescued pigs and the details of their breed, sex, and age

	Pig ID	Gender	Date of birth
No.1	D34	♂	2009/9/10
No.2	D554	♂	2004/8/19
No.3	D90	♂	2003/12/12
No.4	L315	♂	2004/4/10
No.5	W851	♂	2009/1/19
No.6	Y281	♂	2006/8/4
No.7	D54	♀	2005/8/1
No.8	D345	♀	2006/9/5
No.9	L301	♀	2006/8/9
No.10	D83	♀	2005/9/2
No.11	Y597	♀	2007/6/1
No.12	Y602	♀	2007/6/1
No.13	Y709	♀	2008/4/10
No.14	B559	♀	2004/8/29
No.15	Y669	♀	2008/2/9
No.16	W156	♀	2006/5/5
No.17	D949	♀	2009/6/22
No.18	D10	♀	2005/7/28
No.19	D424	♀	2007/1/15
No.20	W340	♀	2006/8/29
No.21	D85	♀	2005/9/2
No.22	D801	♀	2005/2/15
No.23	W250	♂	2010/10/22
No.24	W251	♂	2010/10/22
No.25	Y36	♂	2007/11/14
No.26	W179	♂	2010/3/31

Breeds of pigs are identified by the following letters: *D* Duroc, *W* Large White, *L* Landrace, *Y* Middle Yorkshire, *B* Berkshire

health check, hematological tests, and blood plasma biochemical parameters were recorded. Transgenerational effects of radiation exposure were also carried out.

5.2 Methods and Material

1. Animals (Pig)

- ① Twenty-six pigs (16 sows and 10 boars) were rescued. Details of these pigs are shown in Table 5.1.
- ② The control group consisted of six pigs, which were the second generation of the rescued pigs, born from rescued sows and reared at ARSC.

- ③ Blood samples were taken from both rescued pigs and normal confidential adult sows (NCAS), mentioned above, at 4–5 month intervals.
- ④ Sick pigs were euthanized and their organs collected. To understand the exposure level of the rescued pigs, local pigs who had been fed in the exclusion zone, were also collected and analyzed.

2. Methods

- ① The isotopes measurement was carried out by the Isotope Facility for Agricultural Education and Research. The nutrition level is very important for the sows' reproductive performance. To confirm the nutrition level of the rescued sows, in the current study the body weight changes were measured once a month and feed intake was adjusted accordingly. The pigs were fed a commercial pig feed, considered for a sow's diet (Multi Rack, Chubu Shiryo Co. Ltd., Japan), with feed volumes of 1.5–2.0 kg/day/head. The composition of the feed was TDN 75.5%, CP 15.5%, CF 6.0%, and EE 3.5%.

The transgenerational effects of radiation exposure were conducted by producing offspring with the parents that had been irradiated.

- ② Because exposure to ionizing radiation is known to have a lethal effect (El-Shanshoury et al. 2016) on blood cells, this study evaluated ionizing radiation effect on some blood components in pigs. The blood samples were collected once every four or five months and were drawn consistently at around 15:00 h by jugular venipuncture and transferred to tubes containing EDTA (Terumo Venoject II, Tokyo, Japan). Hematology analyses was conducted immediately with the automated pocH-100iV DIFF hematology analyzer (Sysmex Corporation, Japan). The biochemical index also were analyzed immediately by an automatic dry-chemistry analyzer (DRI-CHEM 3500s; Fujifilm Corporation, Japan).

5.3 Results

5.3.1 Exposure Levels in Pigs

After moving pigs out of the alert area to ARSC, the health of some of the rescued pigs deteriorated. Three pigs died within six months; therefore, the present study was planned to check cesium levels in the pigs' bodies and organs. The organs included ovaries or testes, spleen, liver, kidney, psoas major, urine, and blood. Although radiation tests confirmed that the pigs had taken in only non-contaminated food and water while living in the Fukushima area, the results from organ screens were unexpected (Fig. 5.1). Most of the organs tested showed contamination by radiocesium, even though more than 6–9 months had passed since the Fukushima

Fig. 5.1 Cesium levels in different organs of rescued pigs (Bq/kg). Different colored bars represent a different pig

[Daiichi Nuclear Power Plant](#) disaster, and more than 3–6 months had passed since the pigs had been moved outside of the alert area to ARSC. However, our result confirmed that the rescued pigs, despite consuming only non-contaminated feed concentrate and non-contaminated groundwater, had been exposed to radioactive material. It is likely that the exposure was only due to inhaling contaminated air. Samples from August 1st, 2012 had no radiocesium. These data also indicate that the discharge of radiocesium from the body requires a longer period than previously thought. As shown in Fig. 5.1, the highest levels of radiocesium were present in the psoas major.

To better understand the exposure levels for local pigs who had been feeding in the exclusion zone in September 16th, 2011, in the same area we visited another local pig farm with radiation levels of approximately 1.9–3.8 $\mu\text{Sv/h}$ (https://ramap.jmc.or.jp/map/#lat=37.551093857523306&lon=140.96295470535136&z=15&b=std&t=air&s=25,0,0,0&c=20110429_dr). We collected organ samples from these pigs and determined the contamination level of the organs which is shown in Fig. 5.2.

When Figs. 5.1 and 5.2 is compared, the organ radiocesium level of the pigs still feeding in the exclusion zone was nearly ten times higher than the rescued pigs.

Samples were collected from these pigs who fed by grazing, indicating that the pigs most likely acquired the radioactive material from contaminated grass. Again, the highest level of radiocesium was detected in the psoas major muscles, which was consistent with the data collected from the rescued pigs.

Fig. 5.2 Cesium levels in different organs of local pigs (Bq/kg) who were raised in the alert area after Fukushima Daiichi Nuclear Power Plant disaster. Different colored bars represent a different pig

Table 5.2 Bodyweights of the rescued pigs (kg)

Pigs	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	Average
Duroc(♂)	219	259	220						232.7
Duroc(♀)	221	210	219	218	200	221	187	235	213.9
Large white(♂)	180	119	113	179					147.8
Large white(♀)	213	220							216.5
Yorkshire(♂)	220	200							210.0
Yorkshire(♀)	191	159	159	159					167.0
Berkshire(♀)	203								203.0
Landrace(♂)	203								203.0
Landrace(♀)	165								165.0
Date: 2011/7/6									

5.3.2 Reproductive Performance

After being moved to the ARSC, the rescued pigs were allowed some time to recover. The pigs had remained at Fukushima for nearly four months after the accident, dealing with feed shortages, unsanitary stalls, and other environmental stresses. In addition, moving the pigs 140 km to the ARSC induced added stressors, and the animals needed time to become accustom new feeding conditions. When the pigs were moved to the ARSC, the average body weight was determined (Table 5.2).

Fig. 5.3 Relationship between bodyweight change and reproduction
■ Partition

After a two-month recovery period, seven of the sixteen rescued sows gradually showed normal estrous behavior, and mated with boars that also were rescued from Fukushima, and produced offspring. The relationship between body weight and reproductive performance is shown in Fig. 5.3. There was no difference in body weight between reproductive and non-reproductive sows. A total of 7 sows had 15 parturition events and produced 166 piglets, including two malformed piglets (Table 5.3); one piglet had limbs curved disease and the other was intersex. In addition, offspring from the second generation sows who were born from the rescued pigs were produced and reared at ARSC. Six sows had ten parturition events and gave birth to 104 piglets; there were no malformed piglets (Table 5.3).

The present study analyzed sows age on reproductive ability. The age of rescued sows significantly differed between reproductive and non-reproductive sows (Table 5.4).

5.3.3 Hematology Analyses and Biochemical Indices

To check the health of the rescued and control pigs, routine blood tests were performed. The following parameters were measured: WBC, RBC, HGB (Hemoglobin), PLT (platelet count), W- SCR (small white cell rate; lymphocyte), W-MCR (middle

Table 5.3 Comparing of reproductive performance between irradiated sows and non-irradiated sows

	Number of sow	Sow of reproduction	Number of parturition	Litter size	Birth weight	Number of piglets	Male	Female	Malformation
Sow of rescued	16	7	15	11.0	1.1	166	85	79	2
		43.80%					51.2%	47.6%	1.2%
Sow of second generation	6	6	10	10.3	1.3	104	49	55	0
		100%					47.1%	52.9%	0%

Sow of second generation: indicating non-irradiated sow

Table 5.4 Relationship between sow age and reproduction success

	Sow	Birthday	Age of rescued	Age of last parturition	
Reproductive sow	Y709	2008/4/10	3.2	2013/5/31	5.1
	Y669	2008/2/9	3.4	2013/6/23	5.4
	Y597	2007/6/1	4.1	2014/9/8	7.3
	Y602	2007/6/1	4.1	2012/8/12	5.2
	D424	2007/1/15	4.5	2013/3/2	6.1
	D345	2006/9/5	4.8	2012/8/17	6.0
	W340	2006/8/29	4.8	2012/2/17	5.5
Non-reproductive sow	L301	2006/5/5	4.9		
	W156	2005/9/2	5.2		
	D85	2005/9/2	5.8		
	D83	2005/8/1	5.8		
	D54	2005/7/28	5.9		
	D10	2005/2/15	5.9		
	D801	2004/8/29	6.4		
	B559	2004/8/29	6.8		
	D949	2006/8/9	2.0	Died soon after been rescued	

white cell rate; monocyte+ Eosinophil granulocyte + basophilic leukocyte), W-LCR (large white cell rate; Neutrophil), W-SCC (small white cell count), W-MCC (middle white cell count), and W-LCC (large white cell count). As shown in Table 5.5, WBC, W- SCC, W-MCR and W-SCC in the irradiated sows was significantly higher than in the NCAS. This indicates that WBC, lymphocyte, monocyte, eosinophil granulocyte, basophilic leukocyte and neutrophil increased. The RBC, HGB and HCT decreased in irradiated sows, while the MCV and MCH increased.

Plasma biochemical indexes, including TP-P (total protein), ALB-P (albumin), TBIL-P (total bilirubin), GOT/AST-P (aspartate amino-transferase), GPT/ALT-P (alanine amino-transferase), ALP-P (alkaline phosphatase), GGT-P (γ -glutamyltransferase), LDH-P (Lactate Dehydrogenase), LAP-P (leucyl amino-peptidase), CPK-P (creatine kinase), AMYL-P (α -amylase), NH₃-P (ammonia), TCHO-P (total cholesterol), HDL-C-P (HDL cholesterol), TG-P (triglyceride), UA-P (uric acid), BUN- P (Urea nitrogen), CRE-P (creatinine), GLU-P (glucose), Ca-P (calcium), IP-P (phosphorus), Mg-P (magnesium) were also analyzed (Table 5.6). Blood levels of AST, ALP, GGT, LDH, and TBIL, all related to liver function, were higher in the rescued pigs, indicating some level of liver damage. As shown in Table 5.5, with a decrease in RBC, there was an increase in TBIL. This might be further evidence of liver damage. Furthermore, the high levels of TP and low levels of ALB were indicative of globulin level, like an inflammatory disease, and unstable kidney function. Blood levels of kidney-associated BUN and CRE were also higher in the rescued pigs, further indicating kidney abnormalities, which were confirmed by pathologic anatomy. Low levels of triglycerides and deficiencies in magnesium, potassium, and calcium also were confirmed.

Table 5.5 Comparing of hematology analyses

	WBC	RBC	HGB	HCT	MCV	MCH	MCHC	PLT	W-SCR	W-MCR	W-LCR	W-SCC	W-MCC	W-LCC
Average(C) n = 8	124.7	878.8	17.3	58.8	67.1	19.7	29.4	18.3	55.4	10.0	34.6	69.2	12.4	43.1
Average(I) n = 199	155.0	607.1	12.7	43.1	71.1	20.8	29.4	16.9	54.8	10.3	35.0	80.4	15.9	55.3
SD(C)	10.7	168.0	3.0	10.0	1.8	0.5	0.9	7.7	4.1	1.5	3.0	7.3	2.4	5.4
SD(I)	57.5	132.5	3.0	9.9	5.3	1.3	1.0	9.8	11.1	3.3	10.8	28.2	9.0	35.4
FTEST	0.000107	0.008575	0.000776	0.013811	0.001085	0.002688	0.763371	0.777764	0.004882	0.060379	0.000281	0.000586	0.001978	0.000014
FTEST	**	**	**	**	**	**			**		**	**	**	**
TTEST	0.000012	0.000000	0.000000	0.000014	0.000035	0.000019	0.836276	0.675796	0.302388	0.519669	0.299488	0.009514	0.007178	0.000191
TTEST	**	**	**	**	**	**						**	**	**

C control, I irradiated

**p < 0.01

Table 5.6 Comparing of biochemical index

	TP-PiII	ALB-P	TBIL-PiII	AST-PiII	ALT-PiII	ALP-PiII	GGT-PiII	LDH-PiII	LAP-P	CPK-PiII	AMYL-PiII
Average(C)n=8	7.4	5.8	0.1	27.0	30.5	111.2	25.2	407.6	32.8	772.6	1816.9
Average(I)n=199	8.4	4.5	0.4	39.5	42.6	76.2	51.1	432.4	52.1	762.3	1865.0
SD(C)	0.6	0.3	0.0	6.1	2.5	18.0	8.1	80.3	4.2	365.6	268.8
SD(I)	0.8	0.6	0.3	25.9	19.0	34.7	32.8	241.0	21.8	578.2	774.4
FTEST	0.261451	0.115884	0.000000	0.000690	0.000013	0.015134	0.000001	0.001503	0.000003	0.338124	0.003008
FTEST			**	**	**	*	**	**	**		**
TTEST	0.000112	0.000000	0.000000	0.000202	0.000000	0.000015	0.000000	0.985323	0.000000	0.913902	0.335975
TTEST	**	**	**	**	**	**	**		**		
	NH3-PiI	TCHO-PiII	HDL-C-PiII	TG-PiII	UA-PiII	BUN-PiII	CRE-PiII	GLU-PiII	Ca-PiII	IP-P	Mg-PiII
Average(C)n=8	92.8	76.6	25.7	97.6	0.4	13.5	1.8	89.6	11.5	6.1	2.5
Average(I)n=199	139.5	75.1	23.0	42.8	0.4	17.1	3.2	75.4	8.2	5.2	2.3
SD(C)	17.5	16.5	4.2	38.8	0.0	2.2	0.2	13.8	0.7	1.1	0.2
SD(I)	141.6	22.9	6.8	25.4	0.1	17.6	3.1	18.2	2.3	1.1	0.6
FTEST	0.000006	0.056440	0.167306	0.890043	0.015111	0.000012	0.000000	0.633393	0.003480	0.805897	0.026231
FTEST	**				*	**	**		**		*
TTEST	0.000275	0.350530	0.135123	0.000000	0.002806	0.017142	0.000000	0.049646	0.000000	0.003551	0.037189
TTEST	**			**	**	*	**	*	**	**	*

C control, I irradiated

*p < 0.05

**p < 0.01

5.4 Discussion and Conclusion

Because of the lack of a scientifically designed control group, we cannot conclude the exact effects of radiation exposure on the rescued pigs. We attempted to provide a reasonable comparison by performing the same tests and analyses on pigs born and raised at the ARSC without radiation exposure. However, we recognize that these “control” pigs were raised at different times and in different environments, making the comparison imperfect. Nevertheless, to our knowledge, this is the first study to observe the effects of radiation exposure on pigs occurring from a nuclear power accident.

The present study confirmed that the pigs that remained in the evacuated area fed on uncontaminated concentrate and drunk uncontaminated groundwater. Inhaling contaminated air may have been the only way the pigs were exposed to radiation. In addition, radiocesium was detected up to a half a year later after the pigs were moved outside the evacuated area. Radiocesium was not the only radioactive material released after the nuclear power plant accident. Thus, we will continue our study, especially to estimate the iodine exposure level and its effect on thyroid function.

To study transgenerational effects of radiation exposure, we made observations of offspring conceived after the parents had been irradiated. The results revealed that only seven of the sixteen sows rescued displayed estrus behavior that resulted in successful births. Two piglets were malformed. Approximately 40–50 days is required for a sperm cell to develop before appearing in the ejaculate (spermatogenesis) (França et al. 2005). Morbeck et al. (1992) indicated that the total time required for a primary follicle containing one layer of granulosa cells to grow to a diameter of 3.13 mm was 98 days. And that a further 19 days were required to reach preovulatory status. The sows described above were mated 7 and 8 months after the nuclear power plant accident. Bille and Nielsen (Bille and Nielsen 1977) reported that in the birth of 29,886 piglets, congenital malformations occurred in 410 piglets (i.e., 1.4% of the piglets born). In the present study, 1.2% of the piglets were malformed, which is consistent with the data from Bille and Nielsen (Bille and Nielsen 1977).

The nine sows considered infertile showed a significant difference in age when rescued. The reproductive sows were approximately 3.2–4.8 years old, while the non-reproductive sows were approximately 4.9–6.8 years old (Table 5.4). While six years of age is not past the reproductive capabilities of a sow, it is, however, an age more easily affected by environmental stressors. Belstra and See (Belstra and See 2004), described that reproductive success generally increases over the first three to four parities, then begins to decline as sows reach the seventh or eighth parity. Sugimoto et al. (1996) showed that profits material increase up to the fifth parity and only show a slight increase from the sixth to tenth parity. Thus, it could be considered that age of 4.9–6.8 year-old-sows was not a non-reproductive age.

It was also confirmed that body weight did not affect reproductive abilities of sows (Fig. 5.3). Rescued sows consisted of five breeds; each breed has a different standard body weight at maturity, so average body weights were difficult to evaluate for this group of pigs; however, body weights for all rescued sows appeared normal.

Table 5.7 List of pig deaths

	Pig	Sex	Date of Birth	Date of death
No.1	D90	M	2003/12/12	2011/9/9
No.2	L315	M	2004/4/10	2013/2/25
No.3	Y281	M	2006/8/4	2013/6/10
No.4	W250	M	2010/10/22	2013/8/7
No.5	Y36	M	2007/11/14	2015/3/4
No.6	D554	M	2004/8/19	2015/4/24
No.7	W851	M	2009/1/19	2016/1/3
No.8	W179	M	2010/3/31	2016/4/24
No.9	W251	M	2010/10/22	2017/11/28
No.10	L301	F	2006/8/9	2011/9/30
No.11	D949	F	2009/6/22	2012/1/1
No.12	D801	F	2005/2/15	2012/8/31
No.13	D10	F	2005/7/28	2012/3/13
No.14	D424	F	2007/1/15	2013/6/10
No.15	D54	F	2005/8/1	2013/7/24
No.16	Y709	F	2008/4/10	2013/7/24
No.17	W340	F	2006/8/29	2014/10/17
No.18	D345	F	2006/9/5	2015/7/31
No.19	Y602	F	2007/6/1	2015/8/3
No.20	W156	F	2006/5/5	2016/2/4
No.21	D85	F	2005/9/2	2016/3/31
No.22	B559	F	2004/8/29	2016/8/9
No.23	Y669	F	2008/2/9	2017/3/22
No.24	D83	F	2005/9/2	2017/7/26
No.25	Y597	F	2007/6/1	2017/7/31

In addition, the sows' reproductive hormones were also confirmed by assaying for plasma steroid hormones, estradiol and progesterone (data not presented). The non-reproductive sows presented low levels of estradiol and progesterone. This could be the main reason why some sows did not show estrous behavior.

High levels of TP and low levels of ALB indicated high levels of globulin. It is consistent with high levels of WBC. Weiss et al. (2009) reported that inflammatory disorders account for a significant percentage of gynecologic disease, particularly in reproductive-age women. Inflammation is a basic method by which humans respond to infection, irritation, or injury. Inflammation is now recognized as a type of nonspecific immune response, either acute or chronic. High levels of TBIL results in low levels of RBC. Meanwhile, the data of AST, ALP, GGT, LDH, NH3 and TBIL and high levels of CRE and BUN indicate liver and kidney functional disorder.

As of April 27th, 2018, 25 of the rescued pigs have died (Table 5.7), with only one pig still alive. Altogether, the rescued pigs showed high mortality and low

immunity, so a more detailed study of the effects of radiation exposures is needed. Also, the study of radiocesium transfer coefficients for the body and organs is an on-going project that resulted from the rescue of this group of pigs.

Recent events occurring in the Fukushima Daiichi nuclear disaster area have focused attention on studies evaluating the levels of radioactive material in animals and in agricultural products, but less concern has arisen regarding animal health. The radiation exposure levels were most acute during the first 30 days because of the large quantities of short-lived radionuclides present in the exclusion zone. The pigs used in this study were rescued from their pigsties, which were located only about 17 km from the center of the meltdown area, and remained in this area during the most highly radiative time after the meltdown. In medical laboratory animals, the pig is the closest species to human in evolutionary terms, with the exception of primates. As an animal model, the pig is highly regarded by many scientific fields, including comparative biology, developmental biology and medical genetics (Guo and Shi-ming 2015).

Pigs share many physiological similarities with humans, and offers breeding and handling advantages (when compared to non-human primates), making it an optimal species for preclinical experimentation. The adduced examples are taken from the following fields of investigation: (a) the physiology of reproduction, where pig oocytes are being used to study chromosomal abnormalities (aneuploidy) in the adult human oocyte; (b) the generation of suitable organs for xenotransplantation using transgene expression in pig tissues; (c) the skin physiology and the treatment of skin defects using cell therapy-based approaches that take advantage of similarities between pig and human epidermis; and (d) neurotransplantation using porcine neural stem cells grafted into inbred miniature pigs as an alternative model to non-human primates xenografted with human cells (Vodicka et al. 2005).

Thus, the results of the present study also could provide critical information about the health effects of radiation exposure in humans.

We made observations of hair loss over time as shown in Fig. 5.4. This symptom only occurred once, and if the depilation was the result of radiation exposure, the symptoms were less severe than expected. Sieber et al. (1993) indicated that hair loss is dose-dependent for exposures between 1.0 and 15.0 Gy (1.0–15.0 Sv), and occurs in a linear relationship. No further increase in hair loss was observed for doses ≥ 15.0 Gy, as 20–30% of the hair remained.

Fig. 5.4 Depilation of the pigs presented after approximately 18 months after the nuclear power plant accident

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