

Biokinetics and dosimetry of commonly used radiopharmaceuticals in diagnostic nuclear medicine – a review

Supplementary material

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1. PET-Radiopharmaceuticals

Details on the available data for PET-radiopharmaceuticals can be found in the following tables.

Adult F-18	PET	PET/CT	Biokinetic data	Last data point	Bladder voiding interval
Florbetaben (BAY94)	(O'Keefe et al., 2009)AC			3 h (O'Keefe et al., 2009)	2.4 h (O'Keefe et al., 2009)
Choline	(DeGrado et al., 2002)AC	(Janzen et al., 2010)AC	(DeGrado et al., 2002), (Janzen et al., 2010), (Noßke and Brix, 2009), (Zankl et al., 2010)	55 min (DeGrado et al., 2002) 4 h (Janzen et al., 2010)	no void (DeGrado et al., 2002) 1 h (Janzen et al., 2010) 3.5 h (Noßke and Brix, 2009)
DOPA	(Dhawan et al., 1996)AC, NWB (Brown et al., 1998)AC, NWB		(Dhawan et al., 1996), (Brown et al., 1998) NTAC	2 h (Dhawan et al., 1996) 2 h (Brown et al., 1998)	40 min then 70 min: (Dhawan et al., 1996) like (Thomas et al., 1999): (Brown et al., 1998)
FDG	(Mejia et al., 1991)AC, NWB (Deloar et al., 1998b)AC (Deloar et al., 1999)AC (Hays and Segall, 1999)AC, NWB, 2x (Niven et al., 2001) AC, NWB, 2x (Wu et al., 2002)AC, NWB (Koukouraki et al., 2006)AC	(Khamwan et al., 2010)AC	(Mejia et al., 1991) NTAC, (Deloar et al., 1998b) NTAC, (Deloar et al., 1999), (Hays and Segall, 1999) NTAC, (Niven et al., 2001), (Hays et al., 2002), (Wu et al., 2002), (Koukouraki et al., 2006)	PET 2 h, urine 4 h (Mejia et al., 1991) 3 h (Dowd et al., 1991) 84 min (Deloar et al., 1998b) 81 min (Deloar et al., 1999) 90 min (Hays and Segall, 1999) 1 h (Niven et al., 2001) 3 h (Wu et al., 2002) 1 h (Koukouraki et al., 2006) 3 h (Khamwan et al., 2010)	1 h+2 h (Mejia et al., 1991) no dynamic bladder model (Deloar et al., 1998b) varying, then 3 h (Dowd et al., 1991) 120-288 min (Hays and Segall, 1999) 20-180 min, then like (Thomas et al., 1999): (Hays et al., 2002) variable (Wu et al., 2002)
FET	(Pauleit et al., 2003)AC (Abe et al., 2006)AC		(Pauleit et al., 2003) NTAC, (Abe et al., 2006)	PET 200 min, urine 5 h (Pauleit et al., 2003) 1 h (Abe et al., 2006)	2 h (Pauleit et al., 2003)
FLT	(Vesselle et al., 2003)AC, NWB (Muzi et al., 2005)AC		(Vesselle et al., 2003) NTAC, (Muzi et al., 2005)	2 h (Vesselle et al., 2003), (Muzi et al., 2005)	single voiding after 6 h (Vesselle et al., 2003)
Fluoride	(Hawkins et al., 1992)AC, NWB (Berding et al., 1995)AC, NWB (Schiepers et al., 1997)AC, NWB (Cook et al., 2010)AC, NWB (Frost et al., 2008)AC, NWB		(Hawkins et al., 1992), (Berding et al., 1995), (Schiepers et al., 1997), (Cook et al., 2010), (Frost et al., 2008)	1 h (Hawkins et al., 1992) 1 h (Berding et al., 1995) 2 h (Schiepers et al., 1997) 1 h (Cook et al., 2010) 1 h (Frost et al., 2008)	
MISO	(Graham et al., 1997)AC, NWB			4 h (Graham et al., 1997)	2 h (Graham et al., 1997)

Table 1.1: Acquisition mode and biokinetic data of F-18 labelled radiopharmaceuticals. Abbreviations: NC: no correction, AC: attenuation correction, CAC: calculated attenuation correction, NWB: not whole body, 2x: study repeated with same subjects, NTAC: normalized time-activity curve.

Adult F-18	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MIRD, MD, MD2, MD3, CM)
Florbetaben (BAY94)	(O'Keefe et al., 2009)	1.5E-2(O'Keefe et al., 2009)	ICRP 106: 2.8E-2 (brain receptor)	3v (O'Keefe et al., 2009)	OL (O'Keefe et al., 2009)
Choline	(DeGrado et al., 2002), (Janzen et al., 2010), (Zankl et al., 2010), (Noßke and Brix, 2009)	m:(2.7E-2) f:(3.7E-2) (DeGrado et al., 2002) 1.7E-2(Noßke and Brix, 2009)		7m+5f p (DeGrado et al., 2002) 6p (Janzen et al., 2010) 1p (Zankl et al., 2010)	MD3: (DeGrado et al., 2002) CM: (Janzen et al., 2010) Other: (Janzen et al., 2010), (Zankl et al., 2010) OL (Noßke and Brix, 2009)
DOPA	(Dhawan et al., 1996), (Brown et al., 1998)	(1.8E-2)(Dhawan et al., 1996)	ICRP 106: 2.5E-2	5p + 5v (Dhawan et al., 1996) 34 (p and v) (Brown et al., 1998)	MD3: (Dhawan et al., 1996) MIRD: (Brown et al., 1998)
FDG	(Mejia et al., 1991), (Dowd et al., 1991), (Deloar et al., 1998b), (Deloar et al., 1999), (Thomas et al., 1999), (Niven et al., 2001) MC, (Hays et al., 2002), (Wu et al., 2002), (Khamwan et al., 2010) MC	(2.4E-2)(Mejia et al., 1991) 2.9E-2(Deloar et al., 1998b) 2.9E-2(Deloar et al., 1999) 1.4E-2(Khamwan et al., 2010)	ICRP 106: 1.9E-2	18v (Mejia et al., 1991) 302p (Dowd et al., 1991) 6v (Deloar et al., 1998b) 6v (Deloar et al., 1999) 5v (Hays and Segall, 1999) (5m+3f) p + (3m+3f) v(Niven et al., 2001) 6v (Wu et al., 2002) 15p (Koukouraki et al., 2006) 35p (Khamwan et al., 2010)	MIRD: (Mejia et al., 1991), (Deloar et al., 1998b), (Deloar et al., 1999), (Wu et al., 2002), (Hays et al., 2002) CM: (Hays and Segall, 1999), (Koukouraki et al., 2006) MD3: (Niven et al., 2001) Other: (Khamwan et al., 2010)
FET	(Pauleit et al., 2003)	1.7E-2(Pauleit et al., 2003)	ICRP 106: 2.3E-2 (amino acids)	7p (Pauleit et al., 2003) 4v (Abe et al., 2006)	MD3 (Pauleit et al., 2003)
FLT	(Vesselle et al., 2003)	m:(2.8E-2), f:(3.3E-2) (Vesselle et al., 2003)		(11m+7f)p (Vesselle et al., 2003) 17p (Muzi et al., 2005)	MD3 (Vesselle et al., 2003) CM (Muzi et al., 2005)
Fluoride			ICRP 80: 2.4E-2	11v+1p (Hawkins et al., 1992) 9p (Berding et al., 1995) 9p (Schiepers et al., 1997) 26v (Cook et al., 2010) 16p (Frost et al., 2008)	CM (Hawkins et al., 1992), (Berding et al., 1995), (Schiepers et al., 1997), (Cook et al., 2010), (Frost et al., 2008), (Blake et al., 2001)
MISO	(Graham et al., 1997)	1.3E-2(Graham et al., 1997)		60p (Graham et al., 1997)	MD2 (Graham et al., 1997)

Table 1.2: Dosimetry-related data of F-18 labelled radiopharmaceuticals Abbreviations: ED: effective dose, EDE: effective dose equivalent (values in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA (Stabin et al., 2005), MIRD: MIRD absorbed fraction method (Loevinger and Berman, 1968b, 1968a; Loevinger et al., 1991; Bolch et al., 2009), MD: MIRDose (Stabin, 1996), CM: Compartment Model, m: male, f: female, MC: S-values corrected for organ masses.

Adult PET	PET	PET/CT	Biokinetic data	Last data point	Bladder voiding interval
C-11-Acetate	(Seltzer et al., 2004) AC		(Seltzer et al., 2004)	76 min (Seltzer et al., 2004)	
C-11-Choline	(Roivainen et al., 2000)AC (Tolvanen et al., 2010)AC		(Roivainen et al., 2000), (Tolvanen et al., 2010) NTAC, (Noßke and Brix, 2009)	40 min (Roivainen et al., 2000) 70 min (Tolvanen et al., 2010)	3.5 h (Noßke and Brix, 2009)
C-11-Methionine	(Deloar et al., 1998a)AC		(Deloar et al., 1998a) NTAC	84 min (Deloar et al., 1998a)	
C-11-PIB	(Scheinin et al., 2007)AC, NWB	(O'Keefe et al., 2009)AC	(Scheinin et al., 2007) NTAC	40-100 min (Scheinin et al., 2007) 60 min (O'Keefe et al., 2009)	2.4 h (O'Keefe et al., 2009)
C-11-PK11195	(Hirvonen et al., 2010)AC (Kumar et al., 2010)AC, NWB		(Hirvonen et al., 2010), (Kumar et al., 2010) NTAC	110 min (Hirvonen et al., 2010) 70 min (Kumar et al., 2010)	2.4 h (Hirvonen et al., 2010) 1 h (Kumar et al., 2010)
Ga-68-DOTANOC		(Pettinato et al., 2008)AC	(Pettinato et al., 2008) NTAC	PET 2 h (Pettinato et al., 2008) Urine 4 h (Pettinato et al., 2008)	40-50 min (Pettinato et al., 2008)
Ga-68-DOTATATE					
Ga-68-DOTATOC	(Koukouraki et al., 2006)AC	(Hartmann et al., 2009)AC	(Koukouraki et al., 2006), (Hartmann et al., 2009) NTAC	1 h (Koukouraki et al., 2006) 2 h (Hartmann et al., 2009)	45 min (Hartmann et al., 2009)
Rb-82-Generator		Rest: (Senthamizhchelvan et al., 2010)AC Pharmacologic stress (Senthamizhchelvan et al., 2011)AC	(Senthamizhchelvan et al., 2010) NTAC (Senthamizhchelvan et al., 2011)	8 min (Senthamizhchelvan et al., 2010)	no void (Senthamizhchelvan et al., 2010), (Senthamizhchelvan et al., 2011)

Table 1.3: Acquisition mode and biokinetic data of C-11 and Ga-68 labelled radiopharmaceuticals.

Abbreviations: NC: no correction, AC: attenuation correction, CAC: calculated attenuation correction, NWB: not whole body, NTAC: normalized time-activity curve.

Adult PET	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MD, MD2, MD3, MIRD CM)
C-11-Acetate	(Seltzer et al., 2004)	(6.2E-3) and 4.9E-3 (Seltzer et al., 2004)	ICRP 106: 3.5E-3	6v (m) (Seltzer et al., 2004)	MD3 (Seltzer et al., 2004)
C-11-Choline	(Tolvanen et al., 2010), (Noßke and Brix, 2009)	4.4E-3 (Tolvanen et al., 2010) 4.1E-3 (Noßke and Brix, 2009)	ICRP 106: 1.1E-2 (realistic maximum)	15p (Roivainen et al., 2000) 7p (Tolvanen et al., 2010)	OL: (Tolvanen et al., 2010), (Noßke and Brix, 2009)
C-11-Methionine	(Deloar et al., 1998a)	5.2E-03 (Deloar et al., 1998a)	ICRP 106: 8.4E-03	5v (Deloar et al., 1998a)	MIRD (Deloar et al., 1998a)
C-11-PIB	(Scheinin et al., 2007), (O'Keefe et al., 2009)	4.7E-3 (Scheinin et al., 2007) 5.3E-3 (O'Keefe et al., 2009)	ICRP 106: 4.3E-3 (brain receptor)	16v (Scheinin et al., 2007) 6v (O'Keefe et al., 2009)	MD3 (Scheinin et al., 2007) OL (O'Keefe et al., 2009)
C-11-PK11195	(Hirvonen et al., 2010), (Kumar et al., 2010)	4.8E-3 (Hirvonen et al., 2010) (4.6E-3) (Kumar et al., 2010)	ICRP 106: 4.3E-3 (brain receptor)	5v (Hirvonen et al., 2010) 9v (Kumar et al., 2010)	OL: (Hirvonen et al., 2010), (Kumar et al., 2010)
Ga-68-DOTANOC	(Pettinato et al., 2008)	1.7E-2 (Pettinato et al., 2008)		9p (Pettinato et al., 2008)	OL (Pettinato et al., 2008)
Ga-68-DOTATATE					
Ga-68-DOTATOC	(Hartmann et al., 2009)	m: 2.2E-2 f: 2.5E-2 (Hartmann et al., 2009)		15p (Koukouraki et al., 2006) (8m+6f)p (Hartmann et al., 2009)	CM (Koukouraki et al., 2006) OL (Hartmann et al., 2009)
Rb-82-Genereator	Calculated doses according to three different biokinetic models (Stabin, 2010) (Senthamizhchelvan et al., 2010), (Senthamizhchelvan et al., 2011)	3.34E-3 (ICRP-model), 1.72E-3 (Leggett et al.-model), 7.97E-4 (Ryan et al.-model) (Stabin, 2010); 1.1E-3 (rest) (Senthamizhchelvan et al., 2010) 1.14E-3 (stress) (Senthamizhchelvan et al., 2011) ¹	ICRP 80: 3.4E-3 (rest)	10v (Senthamizhchelvan et al., 2010), (Senthamizhchelvan et al., 2011)	OL: (Stabin, 2010), (Senthamizhchelvan et al., 2010), (Senthamizhchelvan et al., 2011)

Table 1.4: Dosimetry-related data of C-11 and Ga-68 labelled radiopharmaceuticals.

Abbreviations: ED: effective dose, EDE: effective dose equivalent (doses in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA, MIRD: MIRD absorbed fraction method, MD: MIRDose, CM: Compartment Model, m: male, f: female.

¹ Effective dose calculated according to ICRP 60 in both studies. ED was also calculated using the new ICRP weighting factors: ED = 1.26E-3 mSv/MBq (rest), 1.28E-3 mSv/MBq (stress)

2. Other Radiopharmaceuticals

Details on the available data for non-PET radiopharmaceuticals can be found in the following tables.

Adult Tc-99m	Planar	SPECT/CT	Biokinetic data	Last data point	Bladder voiding interval
Antigranulocyte (Scintimun®)	(Becker et al., 1989) NC, (Becker et al., 1994) NC, (Buchmann et al., 2003) CV		(Becker et al., 1989), whole body, urine and serum (Buchmann et al., 2003)	20h (Becker et al., 1989), 24h (Becker et al., 1994), 24h (Buchmann et al., 2003),	
DMSA	(Arnold et al., 1975) NC		(Arnold et al., 1975)		
DTPA	(Stabin et al., 1992a) CV, renography (Carlsen, 1988) NC		(Stabin et al., 1992a), (Carlsen, 1988)	blood 4h, kidney 30min (Stabin et al., 1992a)	4.8h or fv 0.5 thereafter 4h (Stabin et al., 1992a), 2h (Carlsen, 1988)
ECD (Neurolite®)	(Holman et al., 1989) CV, (Léveillé et al., 1989) NC, (Vallabhajosula et al., 1989) CV, (Léveillé et al., 1992) CV	(Léveillé et al., 1989) SPECT (Léveillé et al., 1992) SPECT	(Holman et al., 1989), (Léveillé et al., 1989), (Léveillé et al., 1992)	48h (Holman et al., 1989), 24h (Vallabhajosula et al., 1989)	2h and 4.8h (Vallabhajosula et al., 1989), (Léveillé et al., 1992) 7 h
HMPAO (Ceretec™)	(Costa et al., 1986) NC, (Soundy et al., 1990) NC, (Brown et al., 1994) CV, (Robins et al., 2000) NC (Bennink et al., 2008) AC, CV, (Léveillé et al., 1992) CV	(Costa et al., 1986) AC, (Soundy et al., 1990) (Léveillé et al., 1992) SPECT	(Costa et al., 1986), (Soundy et al., 1990), labelled leukocytes (Brown et al., 1994), (Robins et al., 2000), labelled monocytes (Bennink et al., 2008)	4.5h (Costa et al., 1986), 24h (Soundy et al., 1990), 24h (Brown et al., 1994), 20h (Bennink et al., 2008)	3.5h (Soundy et al., 1990), 1h (Brown et al., 1994), (Léveillé et al., 1992) 7h
MAA	(Malone et al., 1983) CV		(Malone et al., 1983)	36h (Malone et al., 1983)	
MAG3	(Taylor et al., 1988) CV, (Stabin et al., 1992a) CV		ICRP 80, (Taylor et al., 1988), (Stabin et al., 1992a), urine and plasma samples (Arteaga de Murphy et al., 1999)	210 min (Taylor et al., 1988), blood 3h, kidney 20min (Stabin et al., 1992a)	fv 0.5h and 3h (Taylor et al., 1988), 4.8h or fv 0.5 thereafter between 3h and 4h (Stabin et al., 1992a)
MDP (Medtrote)²	(Weber et al., 1989) CV, 2h post injection (Arteaga de Murphy et al., 1997) NC		blood, urine, kidney (Weber et al., 1989), blood, urine, bone (Arteaga de Murphy et al., 1997)	24h (Weber et al., 1989) 24h (Arteaga de Murphy et al., 1997)	fv 2h thereafter 4.8 h (Weber et al., 1989) fv 3h Arteaga de Murphy et al., 1997)

² According to ICRP MDP belongs to the group of phosphates and phosphonates which also includes pyrophosphates

Pertechnetate	(Hays and Berman, 1977) NC		(Hays and Berman, 1977)	4h (group 1), 8h group 2 (Hays and Berman, 1977)	Fv 4 h (Hays and Berman, 1977)
Small colloids (Nanocoll®9)	(Waddington et al., 2000) NC (Wengenmair et al., 2002),		intraprostatic-injection (Wengenmair et al., 2002), sentinel lymph node technique in breast cancer (Waddington et al., 2000)	24h (Waddington et al., 2000) 17h (Wengenmair et al., 2002)	fv 1h (Wengenmair et al., 2002)
Sestamibi (MIBI)	(Wackers et al., 1989) CV (7 NWB), (Leide et al., 1992) CV		(Wackers et al., 1989), (Leide et al., 1992)	24h (Wackers et al., 1989) and (Leide et al., 1992)	
Technegas Generator	(Péry et al., 2009)		(ICRP, 1998), (Péry et al., 2009)		
Tetrofosmin (Myoview™)	(Smith et al., 1992) CV, AC (Higley et al., 1993) CV		(Smith et al., 1992) (Higley et al., 1993)	48h (Smith et al., 1992) and (Higley et al., 1993)	3.5h (Smith et al., 1992) and (Higley et al., 1993)

Table 2.1: Acquisition mode and biokinetic data of Tc-99m labelled radiopharmaceuticals.

Abbreviations: AC: attenuation correction, CV: conjugate view method, NC: no correction, fv: first void, vi: voiding interval, NWB: not whole body.

Adult Tc-99m	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MD, MD2, MD3, MIRD CM)
Antigranulocyte (Scintimun®)	(Iba molecular, 2009), (European Medicines Agency, 2010)	(1.1E-2) (Iba molecular, 2009), 8.63E-3 (ICRP103) (European Medicines Agency, 2010)		15 p (Becker et al., 1989), 10p (Becker et al., 1994), 12p (Buchmann et al., 2003)	
DMSA	(Arnold et al., 1975)		8.8E-3, ICRP 80	7 v (Arnold et al., 1975)	MIRD: (Arnold et al., 1975)
DTPA	(Stabin et al., 1992a), (Carlsen, 1988), dynamic bladder model (Thomas et al., 1999)	(8.9E-3) 4.8h vi, (5.4E-3) 0.5h fv thereafter 4h vi (Stabin et al., 1992a) (6.4E-3) (Carlsen, 1988)	ICRP 80: 4.9E-3 (3.5h), 3.8E-3 voiding after 1h, 4.1E-3 voiding after 0.5 h	11v (Stabin et al., 1992a) 19p (Carlsen, 1988)	CM, MD (Stabin et al., 1992a), CM, MIRD (Carlsen, 1988)
ECD (Neurolite®)	(Holman et al., 1989), (Vallabhajosula et al., 1989)		ICRP 106: 7.7E-3	16 v (Holman et al., 1989), 16 v (Vallabhajosula et al., 1989), 12v (Léveillé et al., 1989) 7v (Léveillé et al., 1992)	MD: (Holman et al., 1989)

HAMPAO (Ceretek™)	(Soundy et al., 1990), (Brown et al., 1994), dynamic bladder model (Thomas et al., 1999), (Robins et al., 2000), (Bennink et al., 2008)	(1.38E-2) (Soundy et al., 1990), 8.85E-3 (1h vi) (Brown et al., 1994), 7E-3 (Robins et al., 2000), 1.1E-2 (Bennink et al., 2008)	ICRP 80: 9.3E-3	22v (Soundy et al., 1990), 5v (Brown et al., 1994), 10v (Robins et al., 2000), 8p (Bennink et al., 2008), 7v (Léveillé et al., 1992)	MIRD (Soundy et al., 1990), MD, CM (Brown et al., 1994), MD3: (Robins et al., 2000), OL (Bennink et al., 2008)
MAA	(Malone et al., 1983)		ICRP 80: 1.1E-2	17p (Malone et al., 1983)	MIRD (Malone et al., 1983)
MAG3	(Stabin et al., 1992a), dynamic bladder model (Thomas et al., 1999), (Arteaga de Murphy et al., 1999)	(1E-2) 4.8 h vi, (4E-3) 0.5h fv thereafter 4h vi (Stabin et al., 1992a)	ICRP 80: 7E-3, 2.5E-3 voiding after 1h 1.7E-3 voiding after 0.5 h	10v, 3p (Taylor et al., 1988), 8 v (Stabin et al., 1992a)	MIRD: (Taylor et al., 1988), CM, MD: (Stabin et al., 1992a), MD3 CM: (Arteaga de Murphy et al., 1999)
MDP (Medtronate)	dynamic bladder model (Thomas et al., 1999)		ICRP 80 5.7E-3	25p (Weber et al., 1989), 10v (Arteaga de Murphy et al., 1997)	CM, MIRD (Weber et al., 1989)
Pertechnetate	(1976) dynamic bladder model (Thomas et al., 1999) Voxel model, biokinetic data from ICRP 53 (Smith et al., 2000)	“GOLEM” Voxel 69.2 kg: 1.37E-2 MIRD: 1.33E-2 (Smith et al., 2000)	ICRP 80: 1.3E-2, with blocking agent: 4.2E-3	9v group 1, 10v group 2 (Hays and Berman, 1977)	CM (Hays and Berman, 1977) MD3, Monte Carlo code for S value calculation (Smith et al., 2000)
RBC³	dynamic bladder model (Thomas et al., 1999), (Ponto, 1988)		ICRP 80: 7E-3		MIRD (Ponto, 1988)
Small colloids (Nanocoll®)	(Eshima et al., 2000), (Wengenmair et al., 2002), (GE Healthcare, 2008), (Waddington et al., 2000), direct measurements with TLDs in an female humanoid phantom (Law et al., 2003)	7.6E-3 intraprostatic injection (Wengenmair et al., 2002), SLN in breast cancer: 2.11E-2 (Waddington et al., 2000), 2.7E-3 Left Breast injected, 2.5E-3 right breast injected (Law et al., 2003)	ICRP 106: 1.2E-3	10p (Wengenmair et al., 2002), 12p (Waddington et al., 2000)	MIRD, MD3 (Wengenmair et al., 2002), MIRD (GE Healthcare, 2008), MIRD (Waddington et al., 2000)
Sestamibi (MIBI)	dynamic bladder model (Thomas et al., 1999), (Wackers et al., 1989), (Leide et al., 1992)	1.2E-2 rest 9.6E-3 stress Combined: 1.1E-2 (Leide et al., 1992)	ICRP 80: 9E-3 rest 7.9E-3 stress	17v (7 rest and 7 stress, 3 rest and stress) (Wackers et al., 1989), 10p (5 rest, 5 stress) (Leide et al., 1992)	MIRD (Wackers et al., 1989) ICRP (Leide et al., 1992)
Technegas Generator	Lung dose (Burch et al., 1986)		ICRP 80: 1.5E-2		

³ This includes also erythrocytes labelled with pyrophosphate

Tetrofosmin (Myoview™)	(Smith et al., 1992) (Higley et al., 1993)	8.9E-3 rest 7.1E-3 stress (Smith et al., 1992) and (Higley et al., 1993)	ICRP 106: Rest: printer's error, data not available 6.9E-3 stress ICRP 80 7.6E-3 rest 7.0E-3 stress	12v (rest and stress each) (Smith et al., 1992) and (Higley et al., 1993)	MD2 (Smith et al., 1992) and (Higley et al., 1993)
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Table 2.2: Dosimetry-related data of Tc-99m labelled radiopharmaceuticals.

Abbreviations ED: effective dose, EDE: effective dose equivalent (doses in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA, MD: MIRDOSE, MIRD: MIRD absorbed fraction method, CM: Compartment Model, ICRP (ICRP, 1987): this method is very similar to the MIRD absorbed fraction method, TLD: thermoluminescent dosimeter.

Adult	Planar	SPECT/CT	Biokinetic data	Last data point	Bladder voiding interval
Tl-201-Chloride	(Krahwinkel et al., 1988) CV, only testes were imaged shielded from the body-background (Thomas et al., 2005) NC		testes (Thomas et al., 2005) combined with older data for the other organs (Krahwinkel et al., 1988)	216 h (Krahwinkel et al., 1988), 168 h (Thomas et al., 2005)	4.8h (Thomas et al., 2005)
I-123-Iodide			compartment model, refinement of ICRP 53 and ICRP 56 models (Johansson et al., 2003)		
I-123-MIBG	(Verberne et al., 2008) CV, AC,		ICRP 53, no-carrier-added (nca) versus carrier-added (ca) (Verberne et al., 2008)	7v 24h, 2v 48 h (Verberne et al., 2008),	4h (Verberne et al., 2008)
I-123-OIH	renography in normal children (Carlsen, 1988), (Carlsen et al., 1986)		ICRP 53, renal mean transit times do not differ significantly between paediatric and adult normal subjects in normal hydration state (Carlsen, 1988)		2h (Carlsen, 1988)
I-123-IOflupane (DATSCAN™), -FP- CIT	(Booij et al., 1998b) AC, CV		(Booij et al., 1998a, 1998b)	48h (Booij et al., 1998b)	
Ga-67 Citrate	(MIRD, 1973)				

Table 2.3: Acquisition mode and biokinetic data of Tl-201, I-123 and Ga-67 labelled radiopharmaceuticals.

Abbreviations: AC: attenuation correction, CV: conjugate view method, NC: no correction, fv: first void, vi: voiding interval.

Adult	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MD2, MD3, MIRD CM)
TI-201-Chloride	(Krahwinkel et al., 1988), (Thomas et al., 2005), recalculation of Krahwinkel et al. data (Krahwinkel et al., 1988), (Castronovo, 1993)	(9.61E-2) (Krahwinkel et al., 1988) 1.6E-1 (Thomas et al., 2005) (3.76E-1) (Castronovo, 1993)	2.2E-1 ICRP 80, 1.4E-1 ICRP 106	28p (Thomas et al., 2005), 15p (Krahwinkel et al., 1988)	MIRD (Krahwinkel et al., 1988), MD3 (Thomas et al., 2005), MD and ICRP 30 (Castronovo, 1993)
I-123-Iodide	(Johansson et al., 2003), dynamic bladder model (Thomas et al., 1999), Voxel model, bio-kinetic data from ICRP 53 (Smith et al., 2000)	2.7E-1, 35% thyroid uptake (Johansson et al., 2003), “GOLEM” Voxel 69.2 kg: 1.48E-1 MIRD: 2.07E-1, 25% thyroid uptake (Smith et al., 2000)	2.2E-1, 35% thyroid uptake 1.1E-1, 0% thyroid uptake ICRP 80		MD3: (Smith et al., 2000)
I-123-MIBG		men: 2.87E-2 ca, 2.94E-2 nca women: 3.53E-2 ca 3.6E-2 nca (Verberne et al., 2008)	1.3E-2 ca ICRP 80	9v (Verberne et al., 2008),	OL (Verberne et al., 2008)
I-123-OIH	(Carlsen, 1988)	(1.5E-2) (Carlsen, 1988)	1.2E-2 ICRP 80		
I-123-loflupane (DATSCAN™), FP-CIT	(Booij et al., 1998a, 1998b), (GE Healthcare, 2007)	2.35E-2 (Booij et al., 1998a, 1998b) (GE Healthcare, 2007)		12v (Booij et al., 1998b)	CM, MD3 (Booij et al., 1998b)
Ga-67 Citrate	(MIRD, 1973)		1.0E-1 ICRP 80	23p for tissue concentration and 112p for whole body measurements (MIRD, 1973)	

Table 2.4: Dosimetry-related data of TI-201, I-123 and Ga-67 labelled radiopharmaceuticals.

Abbreviations ED: effective dose, EDE: effective dose equivalent (doses in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA, MD: MIRDOSE, MIRD: MIRD absorbed fraction method, CM: Compartment Model.

Adult In-111	Planar	SPECT/CT	Biokinetic data	Last data point	Bladder voiding interval
Antimyosin	(Smith et al., 1999)CV		(Smith et al., 1999)	72 h (Smith et al., 1999)	3.5 h (Smith et al., 1999)
DOTA-lanreotide	(Virgolini et al., 1998)CV (Rodrigues et al., 2006)CV	(Virgolini et al., 1998)SP, NC (Rodrigues et al., 2006)SP, NC	(Virgolini et al., 1998)	96 h (Virgolini et al., 1998) 48 h (Rodrigues et al., 2006)	
DOTATATE	(Forrer et al., 2004)AC		(Forrer et al., 2004)	48 h (Forrer et al., 2004)	
DOTATOC	(Cremonesi et al., 1999)CV, AC (Kwekkeboom et al., 1999)NC (Forrer et al., 2004)AC (Rodrigues et al., 2006)CV	(Cremonesi et al., 1999)SP, AC (Kwekkeboom et al., 1999)SP, NC (Rodrigues et al., 2006)SP, NC	(Cremonesi et al., 1999), (Forrer et al., 2004)	48 h (Cremonesi et al., 1999), (Kwekkeboom et al., 1999), (Forrer et al., 2004), (Rodrigues et al., 2006)	like (Thomas et al., 1999): (Cremonesi et al., 1999)
DTPAOC (OctreoScan™)	(Krenning et al., 1992)NC (Bajc et al., 1994)CV (Stabin et al., 1997)CV (Kwekkeboom et al., 1999)NC (Förster et al., 2001)CV (Helisch et al., 2004)CV	(Krenning et al., 1992) SP, NC (Bajc et al., 1994) SP, NC (Stabin et al., 1997) SP, NC (Kwekkeboom et al., 1999) SP, NC (Förster et al., 2001)SP,AC (Helisch et al., 2004)SP,NC	(Bajc et al., 1994), (Stabin et al., 1997) for 90Y: (Förster et al., 2001), (Helisch et al., 2004)	48 h (Krenning et al., 1992), (Bajc et al., 1994), (Stabin et al., 1997), (Kwekkeboom et al., 1999), (Helisch et al., 2004) 72h (Förster et al., 2001)	2 h: (Förster et al., 2001) 3.5 h:(Krenning et al., 1992), (Bajc et al., 1994) 4.8 h: (Stabin et al., 1997)
Ibritumomab (Zevalin®)	(Wiseman et al., 2003)CV, MCS (Wiseman et al., 2001)CV, MCS (Fisher et al., 2009)AC, MCS	(Wiseman et al., 2003) (Wiseman et al., 2001)	(Wiseman et al., 2003), (Wiseman et al., 2001), (Fisher et al., 2009)	6 d(Wiseman et al., 2003) 6 d(Wiseman et al., 2001) 6 d(Fisher et al., 2009)	

Table 2.5: Acquisition mode and biokinetic data of In-111 labelled radiopharmaceuticals.

Abbreviations: AC: attenuation correction, CV: conjugate view method, NC: no correction, SP: SPECT, MCS: multicenter study.

Adult In-111	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MIRD, MD, MD2, MD3, CM)
Antimyosin	(Smith et al., 1999)	1.5E-1 (Smith et al., 1999)		12p with muscle disease +2 control p (Smith et al., 1999)	MD3: (Smith et al., 1999)
DOTA-lanreotide	(Virgolini et al., 1998) for 90Y(Rodrigues et al., 2006)	1.1E-1(Virgolini et al., 1998)		24p (Virgolini et al., 1998) 45p (Rodrigues et al., 2006)	MD3: (Virgolini et al., 1998) MIRD: (Rodrigues et al., 2006)
DOTATATE				5p (Forrer et al., 2004)	CM: (Forrer et al., 2004)
DOTATOC	(Kwekkeboom et al., 1999) for 90Y(Rodrigues et al., 2006)	5.0E-2(Kwekkeboom et al., 1999)		18p(Cremonesi et al., 1999) 8p (Kwekkeboom et al., 1999) 5p (Forrer et al., 2004) 45p (Rodrigues et al., 2006)	MD3: (Cremonesi et al., 1999), (Kwekkeboom et al., 1999) CM: (Cremonesi et al., 1999), (Forrer et al., 2004) MIRD: (Rodrigues et al., 2006)
DTPAOC (OctreoScan™)	(Krenning et al., 1992), (Bajc et al., 1994), (Stabin et al., 1997), (Kwekkeboom et al., 1999), (Thomas et al., 1999),	(8.0E-2)(Krenning et al., 1992) 6.0E-2(Bajc et al., 1994) 7.3E-2(Stabin et al., 1997) 5.0E-2(Kwekkeboom et al., 1999) 5.2E-2(Förster et al., 2001)	ICRP 106: 5.4E-2	26p (Krenning et al., 1992) 6p (Bajc et al., 1994) 10p (Stabin et al., 1997) 8p (Kwekkeboom et al., 1999) 3p (Förster et al., 2001) 8p (Helisch et al., 2004)	MD2: (Krenning et al., 1992), (Bajc et al., 1994) MD3: (Stabin et al., 1997), (Kwekkeboom et al., 1999), (Förster et al., 2001), (Helisch et al., 2004)
Ibritumomab (Zevalin®)	(Wiseman et al., 2003) MC, (Fisher et al., 2009) MC		ICRP 106: 2.2E-1 (monoclonal antibodies)	56p (Wiseman et al., 2003) 73p (Wiseman et al., 2001) 10p (Fisher et al., 2009)	MD3: (Wiseman et al., 2003), (Wiseman et al., 2001) OL: (Fisher et al., 2009)

Table 2.6: Dosimetry-related data of In-111 labelled radiopharmaceuticals

Abbreviations ED: effective dose, EDE: effective dose equivalent (doses in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA, MD: MIRDSE, MIRD: MIRD absorbed fraction method, CM: Compartment Model, MC: S-values corrected for organ masses.

3. Dosimetry Data in Paediatric Nuclear Medicine

Children PET	PET	Biokinetic data	Last data point	Bladder voiding interval
F-18-FDG	(Ruotsalainen et al., 1996)CAC, NWB (Niven and Nahmias, 2003)CAC for brain, NC for chest, NWB	(Ruotsalainen et al., 1996), (Niven and Nahmias, 2003)	84 min (Ruotsalainen et al., 1996) 90 min (Niven and Nahmias, 2003)	individual (Ruotsalainen et al., 1996) no void (Niven and Nahmias, 2003)
F-18-Fluoride				
C-11-PK11195	(Kumar et al., 2010)AC, NWB	(Kumar et al., 2010)	70 min (Kumar et al., 2010)	1h (Kumar et al., 2010)

Table 3.1: Acquisition mode and biokinetic data of F-18, C-11, Ga-68 and Rb-82 labelled radiopharmaceuticals for paediatric use.

Abbreviations: AC: attenuation correction, CAC: calculated attenuation correction, CV: conjugate view method, NC: no correction, NWB: not whole body.

Children PET	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq]	Participants	Code (OL, MD2, MD3, MIRD, CM)
F-18-FDG	(Ruotsalainen et al., 1996), (Niven and Nahmias, 2003), (Gelfand, 2009)	4.3E-1(Ruotsalainen et al., 1996) 2.1E-1 (Niven and Nahmias, 2003) 15y: 3.0E-2 10y: 3.8E-2 5y: 5.7E-2 1y: 9.4E-2(Gelfand, 2009)	15y: 2.4E-2 10y: 3.7E-2 5y: 5.6E-2 1y: 9.5E-2 ICRP 106	21 newborn p (Ruotsalainen et al., 1996) 10 newborn p (Niven and Nahmias, 2003)	other (Ruotsalainen et al., 1996), (Niven and Nahmias, 2003)
F-18-Fluoride	(Gelfand, 2009)	15y: 2.9E-2 10y: 4.6E-2 5y: 7.6E-2 1y: 1.5E-1(Gelfand, 2009)	15y:(3.4E-2) 10y:(5.2E-2) 5y:(8.6E-2) 1y:(1.7E-1) ICRP 53		
C-11-PK11195	(Kumar et al., 2010)	13-17y: (5.3E-3) 8-12y: (7.7E-3) 4-7y: (1.2E-2) (Kumar et al., 2010)	15y: 5.5E-3 10y: 8.6E-3 5y: 1.4E-2 1y: 2.6E-2 ICRP 106 (brain receptor)	22p (Kumar et al., 2010)	OL (Kumar et al., 2010)

Table 3.2: Dosimetry-related data of F-18, C-11, Ga-68 and Rb-82 labelled radiopharmaceuticals for paediatric use.

Abbreviations: ED: effective dose, EDE: effective dose equivalent (doses in brackets refer to EDE), v: volunteers, p: patients, OL: OLINDA, MD: MIRDOSE, CM: Compartment Model, y: year(s), Age/Weight: 15y-55kg, 10y-32kg, 5y-19kg, 1y-9.8kg, newborn-3.4kg (Cristy & Eckerman (Cristy and Eckerman, 1987)).

Children Tc-99m	Planar	Biokinetic data	Last data point	Bladder voiding interval
DMSA	(Evans et al., 1996) + (Smith et al., 1996) CV	(Evans et al., 1996)	(Evans et al., 1996) 24h 23 p, 30h 14p	varying, age dependent
HMPAO	(Vestergren et al., 1992) CV	(Vestergren et al., 1992)	24h (Vestergren et al., 1992)	3.5h (Vestergren et al., 1992)
MAG3	(Stabin et al., 1992b) CV	kidney, urine (Stabin et al., 1992b)	20min kidney (Stabin et al., 1992b)	variable, age dependent (Stabin et al., 1992b)
Per technetate		dynamic bladder model (Dimitriou et al., 1987)		

Table 3.3: Acquisition mode and biokinetic data of Tc-99m labelled radiopharmaceuticals for paediatric use.

Abbreviations: AC: attenuation correction, CV: conjugate view method, NC: no correction.

Children Tc-99m	Organ doses	ED (EDE) [mSv/MBq]	ICRP data [mSv/MBq] (ICRP 80)	Participants	Code (OL, MD, MD2, MD3, MIRD CM)
DMSA		(Smith et al., 1996): normal renal function: ED = 0.98 mSv (discrete phantoms) and 0.91 mSv (interpolated phantoms), renal pathology: 0.9 mSv and 0.77 mSv, biokinetic data from (Evans et al., 1996)	15y: 1.1E-2 10y: 1.5E-2 5y: 2.1 E-2 1y: 3.7 E-2	24 p (15 normal renal function, 9 renal pathology) (Evans et al., 1996)	MD3: (Smith et al., 1996)
HMPAO	(Vestergren et al., 1992)	15y: 8.8E-3 10y: 1.3E-2 5y: 2.0 E-2 1y: 3.7 E-2 Newborn: 8.5E-2	15y: 1.1E-2 10y: 1.7E-2 5y: 2.7 E-2 1y: 4.9 E-2	8p aged between 7 weeks and 18 y (Vestergren et al., 1992)	
MAG3	(Stabin et al., 1992b)		15y: 7.0E-3 10y: 1.1E-2 5y: 1.4 E-2 1y: 2.7 E-2	4p (8d, 2.5y, 5y, 14y) (Stabin et al., 1992b)	CM, MD (Stabin et al., 1992b)
Per technetate	Bladder wall and gonads. Direct radionuclide cystography (Dimitriou et al., 1987) Voxel model, biokinetic data from ICRP 53 (Smith et al., 2000)	"Baby" 8 weeks, 4.2 kg: Voxel: 2.29E-1, MIRD: 1.73E-1 "Child" 7 y, 21.7 kg: Voxel: 4.54E-2, MIRD: 3.97E-2	15y: 1.7E-2 10y: 2.6E-2 5y: 4.2 E-2 1y: 7.9 E-2	36p (Dimitriou et al., 1987)	MIRD (Dimitriou et al., 1987) MD3 (Smith et al., 2000)

Table 3.4: Dosimetry-related data of Tc-99m labelled radiopharmaceuticals for paediatric use. Abbreviations: ED: effective dose, EDE: effective dose equivalent, v: volunteers, p: patients, OL: OLINDA, MD: MIRDSE, CM: Compartment Model, y: year(s), Age/Weight: 15y-55kg, 10y-32kg, 5y-19 kg, 1y-9.8 kg, newborn-3.4kg (Cristy and Eckerman, 1987)

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