

Somatic Cell Nuclear Transfer (Cloning) Efficiency

The overall efficiency of cloning is typically between 0 and 3 % (number of live offspring as a percentage of the number of nuclear transferred oocytes), irrespective of the species, the donor cell type or technique. However, this is the cumulative result of losses at each stage of the cloning process, of which there are several. The following tables provide a summary of the data for each published report on somatic cell (fetal to adult cells) nuclear transfer to date (but does not include the cloning data from commercial companies). Where the appropriate data was made available, the table provides cloning efficiency for each major stage of the process:

% Embryos formed from NT Oocytes: % of morula and/or blastocysts formed from the number of NT (nuclear transfer) oocytes created. The number of NT oocytes is the number of oocytes that were enucleated and injected or fused with donor nuclei. In some reports, only the number of oocytes cultured, or surviving activation or injection is given and the figures are denoted by * with a corresponding footnote.

No. Implantation Sites: This column refers to mice only, and shows how many fetuses implanted into the uterus but were subsequently reabsorbed.

No. Pregnant (no. of recipients): This column is provided for each livestock species. The time of pregnancy confirmation is species dependent. (no. of recipients) refers to the total number of recipients to which embryos were transferred.


No. Pregnancies Lost: Refers to the number of recipients which had lost their fetuses at various stages throughout gestation.

Live Offspring (% embryos transferred): Refers to the number of live offspring born and is also given as a % of the total number of embryos transferred (normally morula or blastocysts, however some studies transfer 2,4,and 8 cell).

No. Survived: Refers to the number of live offspring which survived.

CE: Cloning Efficiency is the number of live offspring expressed as a % of the total number of NT oocytes (this is generally the number of oocytes injected or fused but depending on the data this may refer to, for example, the number of oocytes surviving injection or the number cultured. Furthermore it should be noted that in many studies, not all of the embryos that developed are transferred to recipient females).




Ref: The subscript refers to the reference bibliography provided at the bottom of this article.

	Donor Cell Age	Donor Cell	% Embryos formed from NT Oocytes	No. Implantation Sites	Live Offspring (% embryos transferred)	No. Survived	CE Ref
	Adult	Cumulus			31 (2.2%)	22	1.3% 1
					86 (2.3%)	80	1.1 % 2
			42.1%		7 (23.3%)	4	5.8% 3
					3 (0.7%)	0	? 4
			46.0%		6 (2.0%)	?	0.9% 5
					7 (2.7%)	?	2.3% 5
			52.8%		9 (5.3%)	?	2.8% 5
		Fibroblasts			3 (1.1%)	1	0.4% 6
	21.8%*		134	5 (1.7%)	5	0.3% 7	
		Newborn	Sertoli	23.6%**	235	16 (3.6%)	11
	Fetal	Fibroblasts	16.4%	73	5 (1.1%)	2	0.2% 9
		Gonad	55.1%		6 (2.7%)	5	1.5% 2

No. of NT oocytes except * no. of surviving oocytes, ** no. oocytes cultured



Donor Cell Age	Donor Cell Type	% Embryos formed from NT Oocytes	No. Pregnant (no. recipients)	No. Pregnancies Lost	Live Offspring (% embryos transferred)	No survived	CE	
							Ref	
Adult	Cumulus	39.4%	3 (3)	0	5 (83.3%)	2	5% 10	
			6 (34)	3	3 (7.3%)	3	0.9% 11	
	Oviduct	39.3%	2 (2)	0	3 (75%)	2	2% 10	
			4 (14)	2	2 (11.8%)	2	0.8% 11	
	Uterine		3 (7)	2	2 (14.2%)	0	2% 11	
	Granulosa	69.4%			10 (10%)	10	1.8% 12	
					2 (2.7%)	1	0.5% 13	
	Mammary Gland	16.1%	2 (2)	1	1 (25%)	1	0.4% 14	
		16.8%	4 (31)	2	2 (4.4%)	2	0.7% 15	
	Muscle	14.2%	8 (20)	4	4 (15.3%)	1	0.8% 16	
	Fibroblasts	53.3%	5 (12)	4	1 (6.25%)	0	1.1% 14	
			1 (5)	0	1 (16.7%)	0	0.6% 17	
		11.9%	15 (36)	9	6 (7.4%)	4	0.5% 18	
		16.5%	6 (11)	5	1 (3.8%)	1	0.3% 19	
			24 (48)	12	12 (20.3%)	4	2.8% 11	
		31.1%	6 (37)	4	2 (4.6%)	1	0.8% 15	
	New-born	Fibroblasts		5 (13)	3	2 (12.5%)	2	1.1% 11
		Liver		4 (8)	2	2 (20%)	1	1.3% 11
		testis		1 (1)	1	0	/	0% 11
	Fetal	Fibroblasts	4.6%	17 (32)	11	6 (7.6%)	6	0.3% 20
22.7%			8 (12)	7	2 (8.7%)	1	0.4% 21	
11.7%			5 (12)	5	0	/	0% 19	
			2 (6)	1	1 (14.3%)	1	3.8% 11	
Germ Cells		22.7%	8 (17)	7	1 (3.1%)	0	0.2% 22	
Liver			1 (3)	1	0	/	0% 11	

	Donor Cell Age	Donor Cell	% Embryos formed from NT Oocytes	No. Pregnant (no. recipients)	No. Pregnancies Lost	Live Offspring (% embryos transferred)	No. survived	CE Ref
	Adult	Granulosa		2 (10)	1	5 (0.8%)	5	0.1% 23
	Fetal	Fibroblasts				1 (0.9%)	1	0.2% 24
		Somatic				4 (0.7%)	4	0.5% 25
	Adult	Mammary Gland	10.5%	1 (13)	0	1 (3.4%)	1	0.4% 26
	Fetal	Fibroblasts	27.3%	5 (16)	2	3 (7.5%)	2	1.7% 26
			13.6%	11 (24)	2	7 (10.4%)	5	1.4% 27
				39 (78)	31	4 (3.3%)	0	? 28
	Adult	Granulosa		4 (9)		7 (7.3%)	6	? 29.
		Cumulus		2 (29)	0	3 (1.3%)	1	0.7% 30
	Fetal	Fibroblasts		5 (13)	0	6 (6.2%)	3	1.6% 31
		Somatic				3 (2.7%)	3	1.1% 32

* no. oocytes surviving NT

REFERENCES

1. Wakayama *et al.* (1998). *Nature*, 394, 369-374;
2. Wakayama and Yanagimachi (2001). *Molecular Reproduction and Development*, 58, 376-383;
3. Baguishi and Overstrom (2000). *Theriogenology*, 6, 53, 209;
4. Zhou *et al* (2000). *Cloning*, 2, 35-43.
5. Wakayama and Yanagimachi (2001). *Reproduction*, 122, 49-60.
6. Wakayama and Yanagimachi (1999). *Nature Genetics*, 22, 127-128.
7. Ogura *et al* (2000). *Molecular Reproduction and Development* 57, 55-59.
8. Ogura *et al* (2000). *Biology of Reproduction*, 62, 1579-1584.
9. Ono *et al* (2001). *Biology of Reproduction*, 64, 44-50.
10. Kato *et al* (1998). *Science*, 282, 2095- 2098.
11. Kato *et al* (2000). *Journal of Reproduction and Fertility*, 120, 231-237.
12. Wells *et al* (1999). *Biology of Reproduction*, 60, 996-1005.
13. Wells *et al* (1999). *Theriogenology* 51, 217.
14. Zakhartchenko *et al* (1999). *Molecular Reproduction and Development*, 54, 264-272.
15. Kishi *et al* (2000). *Theriogenology*, 54, 675-684.
16. Shiga *et al* (1999). *Theriogenology*, 52, 527-535.
17. Renard *et al* (1999). *Lancet*, 353, 1489-1491.
18. Kubota *et al* (2000). *PNAS*, 97, 990-995.
19. Hill *et al* (2000). *Biology of Reproduction*, 62, 1135-1140.
20. Lanza *et al* (2000). *Science*, 288, 665-669.
21. Zakhartchenko *et al* (1999). *Journal of Reproduction and Fertility*, 115, 325-331.
22. Zakhartchenko *et al* (1999). *Molecular Reproduction and Development*, 52, 421-426.
23. Polejaeva *et al* (2000). *Nature*, 407, 86-90.
24. Onishi *et al* (2000). *Science*, 289, 1188-1190.
25. Betthausen *et al* (2000). *Nature Biotechnology*, 18, 1055-1059.
26. Wilmut *et al* (1997). *Nature*, 385, 810-813.
27. Schnieke *et al* (1997), *Science*, 278, 2130-2133.
28. Denning *et al* (2001), *Nature Biotechnology*, 19, 559-62.
29. Keefer *et al* (2000). *Biology of Reproduction*, 62, 218.
30. Zou *et al* (2001), *Cloning*, 2, 35-44.
31. Keefer *et al* (2001), *Biology of Reproduction*, 64, 849-856.
32. Baguishi *et al* (1999). *Nature Biotechnology*, 17, 456-461.

This data was compiled by Lesley Paterson, Scientific Secretary to Ian Wilmut, Gene Expression and Development, Roslin Institute. August 2001.