Downstream process development for efficient purification of adenovirus

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This application note describes the development of downstream chromatography steps for purification of adenovirus from HEK293 cell culture harvest. After screening of 11 different anion exchange chromatography adsorbents in small scale, a resin and a membrane adsorber were selected for the capture step. Process conditions were optimized and polishing steps were included for further reduction of impurities to meet regulatory requirements. The two developed downstream processes were compared in larger scale, using 3 L cell culture harvest. Although a higher impurity reduction was obtained using the resin for the capture step, the overall process outcome shows a comparable performance between the developed two-step chromatography processes as well as between scales.

Introduction

Adenovirus is evaluated as vaccine delivery system in many preclinical and clinical studies of various infectious diseases (1). Adenovirus is also explored as a potential viral vector for gene therapy and as an oncolytic virus. To enhance productivity and to produce more effective and safer vaccines, several generations of recombinant adenovirus vectors have been developed (2). The most studied adenovirus vector is the first generation of recombinant adenovirus serotype 5 (AdV5), making this a suitable system for development of a process for adenovirus production.

This work is part of a project for development of an adenovirus production process, ranging from upstream virus production to a purified sterile-filtered bulk product (3). Processes for upstream adenovirus production, release, and filtration have been developed previously (4–7). This study focuses on development and optimization of downstream process conditions for efficient purification of the virus. Adsorbents evaluated in 1 mL columns were the Capto™ Q, Capto Q ImpRes, Capto adhere, Capto adhere ImpRes, Capto DEAE, Q Sepharose™ Fast Flow, Q Sepharose XL, DEAE Sepharose Fast Flow, and ANX Sepharose Fast Flow resins as well as the ReadyToProcess™ Adsorber Q membrane for the capture step, and Capto Core 700 and Sepharose 4 Fast Flow resins for the polishing step. Two downstream processes were developed and scaled up to purification of adenovirus from 3 L cell culture harvest.

Materials and methods

Virus propagation and sample preparation

HEK293.2sus cells (ATCC), grown in HyClone™ CDM4HEK medium in the Xcellerex™ XDR-10 or ReadyToProcess WAVE™ 25 bioreactor system, were infected with AdV5 coding for green fluorescent protein (GFP). The cells were lysed in the bioreactor with 0.5% Tween™ 20 during mixing for 4 h. Simultaneously, 20 U/mL Benzonase™ was added to digest host cell DNA (hcDNA). Clarification of the harvest material was performed by normal flow filtration (NFF), using a combination of ULTA™ 2 µm and 0.6 µm GF filters for removal of cell debris and for an initial impurity reduction. Tangential flow filtration (TFF) was conducted on ÄKTA™ flux 6 filtration system, using a hollow fiber filter with a nominal molecular weight cut-off of M_r 300 000 for concentration and buffer exchange to 20 mM Tris, pH 8.0. Sodium chloride was used for sample conditioning prior to the capture step.

Development of adenovirus capture step

Screening of dynamic binding capacity (DBC) was performed in 1 mL prepacked HiTrap™ columns for the resins and in a 1 mL ReadyToProcess Adsorber Q capsule for the membrane, using the ÄKTA pure 25 chromatography system. DBC was determined at different NaCl concentrations in 20 mM Tris, pH 8.0 (Table 1). Load of sample subjected to TFF was performed at a residence time of 10 min for the column and 0.2 min for the capsule, until breakthrough of virus.

Optimization of elution conditions

Based on the results from the DBC screening, Capto Q, Capto Q ImpRes, Q Sepharose XL, and Capto adhere ImpRes resins as well as the ReadyToProcess Adsorber Q membrane were selected for further evaluation. Linear elution gradient was evaluated in 1 mL prepacked columns for the selected resins, and for the membrane, a 1 mL membrane capsule was used. The columns and capsule were equilibrated with 20 mM Tris, pH 8.0 + 300 mM NaCl (0 mM NaCl for Capto adhere ImpRes). Sample load was performed at 80% of DBC. Fractions were collected for analysis throughout the elution gradient up to 700 mM NaCl.

Table 1. DBC indicated as virus particles (vp)/mL resin

	NaCl							
	0 mM	100 mM	200 mM	300 mM	350 mM	400 mM	450 mM	480 mM
Capto Q	1.51×10^{11}		2.32×10^{11}	3.78×10^{11}*	3.78×10^{11}*	3.78×10^{11}*		
Capto Q ImpRes	1.81×10^{11}	2.01×10^{11}	2.12×10^{11}	3.75×10^{11}*	5.63×10^{11}*	7.04×10^{11}*	7.04×10^{11}*	6.57×10^{11}*
Capto adhere	1.61×10^{11}	1.61×10^{11}	1.31×10^{11}					
Capto adhere ImpRes	2.22×10^{11}	2.22×10^{11}	2.01×10^{11}	2.12×10^{11}				
Capto DEAE	1.21×10^{11}			3.02×10^{10}				
Q Sepharose Fast Flow		9.07×10^{10}	1.01×10^{11}					
Q Sepharose XL	1.21×10^{11}		2.22×10^{11}	2.01×10^{11}				
DEAE Sepharose Fast Flow	1.31×10^{11}		9.07×10^{10}					
ANX Sepharose Fast Flow	1.11×10^{11}		1.11×10^{11}					
ReadyToProcess Adsorber Q nano, 1 mL				1.11×10^{12}				

*DBC was determined with sample from a different preparation.

Capto Q, Capto Q ImpRes, and ReadyToProcess Adsorber Q were selected for further optimization, and step elution conditions were evaluated for these adsorbents. After the load step, a wash step with as high NaCl concentration as possible without breakthrough of virus, followed by a step for complete virus elution at an as low increase in conductivity as possible, was desired to avoid coelution of DNA with the virus. The performance of ReadyToProcess Adsorber Q was evaluated with samples subjected to NFF only or to NFF followed by TFF.

Resin evaluation for adenovirus polishing step

Capto Core 700 (prepacked in 1 mL HiTrap column) and Sepharose 4 Fast Flow (packed in HiScale™ 16/40, 71 mL column volume [CV]) were evaluated for the polishing step. Material purified in the evaluated capture steps, using Capto Q, Capto Q ImpRes, and ReadyToProcess Adsorber Q, was used as sample. A sample load volume of 0.1 CV was used with Sepharose Fast Flow and up to 30 CV was loaded onto Capto Core 700. To determine largest possible sample load volume at accepted virus purity for Capto Core 700, fractions were collected throughout the sample load phase and analyzed for impurity content.

Scale-up of adenovirus capture and polishing steps

Two processes—Process 1 using samples subjected to TFF and a combination of Capto Q ImpRes anion exchange resin and Capto Core 700 resin; and Process 2 using samples subjected to NFF and a combination of ReadyToProcess Adsorber Q anion exchange membrane and Sepharose 4 Fast Flow size exclusion chromatography (SEC) resin—were scaled up for processing of 3 L cell culture harvest. For capture, Capto Q ImpRes was packed in a HiScale 26 column (88 mL), whereas a 150 mL membrane capsule was used for ReadyToProcess Adsorber Q. For polishing, Capto Core 700 was packed in a HiScale 16 column (10 mL) and Sepharose 4 Fast Flow was packed in a HiScale 50 column (382 mL). Columns were operated on the ÄKTA pure 150 system. After the polishing step, a second TFF step was included for concentration, formulation, and final sterile filtration. Processes were performed in duplicate.

Analytical methods

Total virus titer was analyzed in triplicate samples by qPCR using PureLink™ Viral RNA/DNA Mini Kit, TaqMan™ Universal PCR Master mix, and forward and reverse primers for hexon DNA and TaqMan MGB 6-FAM probe on the StepOnePlus™ Real-Time PCR System (all Applied Biosystems). Human AdV5 DNA (3.1×10^7 copies/mL) (ViraPur) was used as standard.

Infectious virus titer was analyzed in triplicate samples by automated fluorescence microscopy of live cells using the IN Cell Analyzer, and the images were analyzed for GFP signal (coded by virus) with a methodology similar to $TCID_{50}$.

Viral and total protein were analyzed by multiplex fluorescent SDS-PAGE and Western blotting. For total protein, Cy™5-labeling was employed using the Amersham™ QuickStain prelabeling kit. For viral proteins, a polyclonal anti-Adv5 primary antibody (Abcam) and a Cy3-labeled secondary antibody were used.

A HPLC method was used for analysis of intact virus particles, using a 1 mL Tricorn™ 5/50 column packed with Q Sepharose XL. Elution was performed with a gradient of NaCl in 20 mM Tris, pH 7.5 at a flow rate of 1.5 mL/min.

A BCA assay kit (Thermo Scientific) with an albumin standard was used for analysis of total protein concentration, and total DNA was determined with Quant-iT™ PicoGreen™ dsDNA Reagent (Invitrogen). Analyses were performed in duplicate.

Concentration of host cell protein (HCP) was determined with a HEK293 HCP ELISA kit (Cygnus).

Concentration of hcDNA was determined in triplicate samples by qPCR (reagents from Applied Biosystems), using primers for GAPDH (Invitrogen) and purified HEK293 DNA as standard. Samples were prepared using PrepSEQ™ Residual DNA Sample Preparation kit and MagMax™ Express 96 purification instrument (Life Technologies).

Results and discussions

Adenovirus capture step

A comprehensive screening of anion exchange and multimodal chromatography adsorbents was conducted. Miniaturized high-throughput screening tools, such as 96-well filter plates could not be used, as the adenovirus analysis methods were not compatible with such formats. Instead screening was conducted in 1 mL HiTrap columns, which provided sufficient sample volume for detection of the virus with available methods. As expected, the membrane as well as resins based on a smaller bead size, thereby providing a larger surface area for virus binding, offered the highest capacity (Table 1).

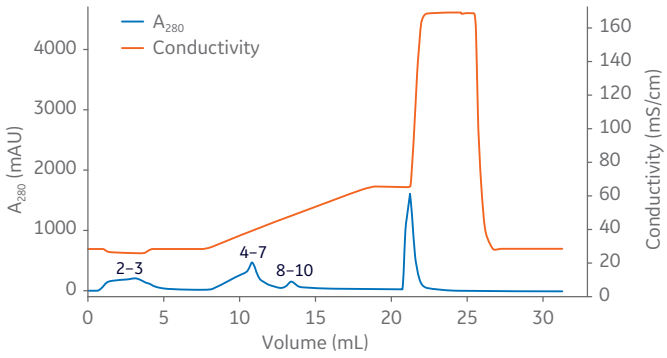
In linear elution gradient experiments, Capto Q ImpRes and Capto Q provided good separation of adenovirus from impurities and were thus selected for further evaluation (Fig 1).

Although ReadyToProcess Adsorber Q provided insufficient virus purity using a linear elution gradient (Fig 2), the membrane was also selected for further evaluation due to its high binding capacity.

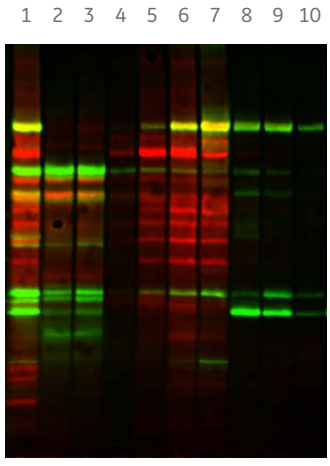
As it was discovered during process optimization that the required conductivity for complete elution of virus was significantly higher in step elution gradient compared with linear elution gradient for both Capto Q and Capto Q ImpRes (Fig 3), linear elution gradient was selected for the resins because the higher the elution conductivity for the virus, the higher the risk of coelution of the virus with DNA. DNA is negatively charged and binds strongly to anion exchangers, and longer DNA sequences (e.g., incomplete fragmented DNA after Benzonase treatment) binds stronger than shorter DNA fragments. Lower elution conductivity resulted in reduced hcDNA in the virus elution pool.

(A)

Sample:	adenovirus subjected to TFF in 20 mM Tris, pH 8.0 + 300 mM NaCl
Resin:	Capto Q ImpRes
Column:	HiTrap 1 mL
Load:	3.0×10^{11} VP /mL resin (80% of Q_{B10}, 10 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 300 mM NaCl
Wash:	3 CV of binding buffer
Elution buffer:	20 mM Tris, pH 8.0 + 300 to 700 mM NaCl in 11 CV
System:	ÄKTA pure 25



(B)

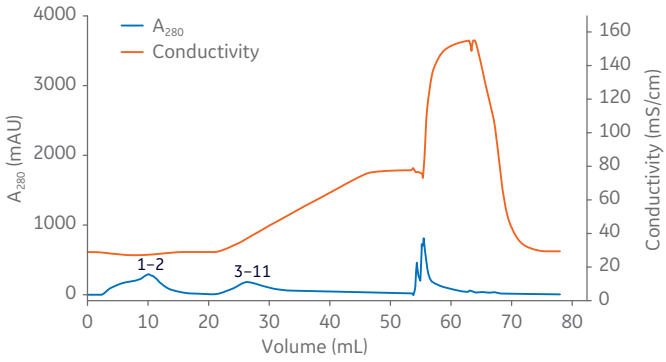


1: start material
2: flowthrough
3: wash
4 to 7: first elution peak (HCP)
8 to 10: elution peak (virus)

Fig 1. (A) Chromatogram from Capto Q ImpRes, employing linear elution gradient. (B) Collected fractions were analyzed by multiplex fluorescent SDS-PAGE and Western blot (green = viral proteins, red = HCP). Free virus proteins were removed in the flowthrough and wash. Intact virus particles in eluate were confirmed by HPLC analysis.

(A)

Sample:	adenovirus subjected to TFF in 20 mM Tris, pH 8.0 + 300 mM NaCl
Membrane:	ReadyToProcess Adsorber Q
Capsule:	1 mL
Load:	8.9×10^{11} VP /mL resin (80% of Q_{B10}, 0.2 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 300 mM NaCl
Wash:	10 CV of binding buffer
Elution buffer:	20 mM Tris, pH 8.0 + 300 to 700 mM NaCl in 25 CV
System:	ÄKTA pure 25



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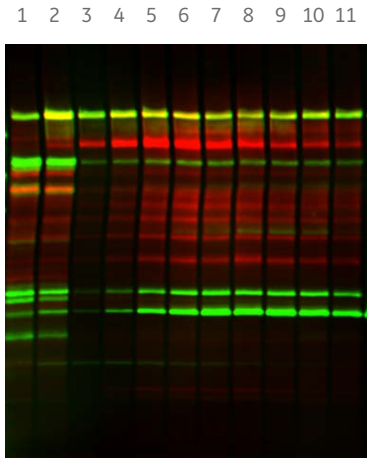


1: flowthrough
2: wash
3 to 11: elution peak (no resolution between HCP and virus)

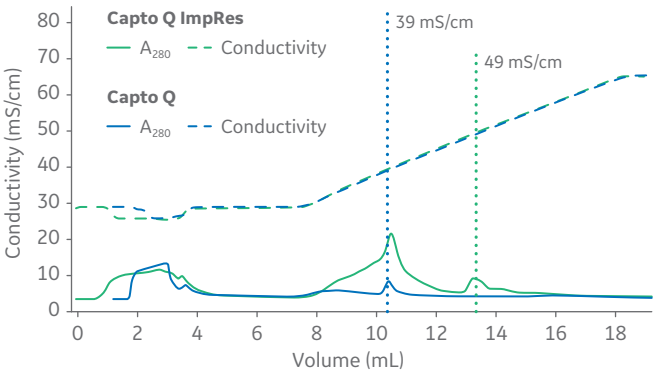
Fig 2. (A) Chromatogram from ReadyToProcess Adsorber Q, employing linear elution gradient. (B) Collected fractions were analyzed by multiplex fluorescent SDS-PAGE and Western blot (green = viral proteins, red = HCP). Free virus proteins were removed in the flowthrough and wash. Intact virus particles in eluate were confirmed by HPLC analysis.

Sample subjected to NFF only was considered for the ReadyToProcess Adsorber Q membrane, as its flow properties allow large volumes to be processed in short time. Omitting the TFF step also allowed exclusion of one unit operation, possibly contributing to an overall recovery improvement. Although the relatively higher impurity content as well as the different composition of the sample subjected to NFF only (constituting cell culture medium, Tween 20, and Benzonase), omitting the TFF step provided improved results in terms of adenovirus purity and recovery for the membrane. Hence, the sample used for the ReadyToProcess Adsorber Q was only subjected to clarification by NFF before loaded onto the membrane.

Results from adenovirus capture using selected adsorbents are summarized in Table 2. As shown, the resins provided improved impurity reduction over the membrane. Reduction of total protein was not affected by choice of elution mode, whereas DNA reduction was clearly improved by using a linear elution gradient with the resins. For the membrane, a step elution gradient was employed.

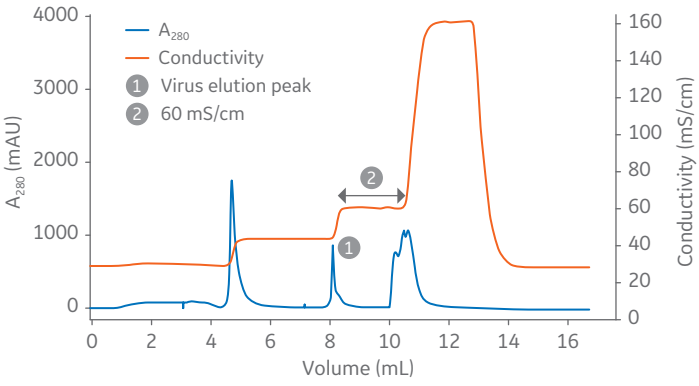
(A)

Sample:	adenovirus subjected to TFF in 20 mM Tris, pH 8.0 + 300 mM NaCl
Resin:	Capto Q ImpRes/Capto Q
Column:	HiTrap 1 mL
Load:	3.0×10^{11} VP /mL resin (80% of Q_{B10}, 10 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 300 mM NaCl
Wash:	3 CV of binding buffer
Elution buffer:	20 mM Tris, pH 8.0 + 300 to 700 mM NaCl in 11 CV
System:	ÄKTA pure 25



(B)

Sample:	adenovirus subjected to TFF in 20 mM Tris, pH 8.0 + 300 mM NaCl
Resin:	Capto Q ImpRes
Column:	HiTrap 1 mL
Load:	3.0×10^{11} VP /mL resin (80% of Q_{B10}, 10 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 300 mM NaCl
Wash:	3 CV 20 mM Tris, pH 8.0 + 480 mM NaCl
Elution buffer:	20 mM Tris, pH 8.0 + 700 mM NaCl
System:	ÄKTA pure 25



(C)

Sample:	adenovirus subjected to TFF in 20 mM Tris, pH 8.0 + 300 mM NaCl
Resin:	Capto Q
Column:	HiTrap 1 mL
Load:	3.0×10^{11} VP /mL resin (80% of Q_{B10}, 10 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 300 mM NaCl
Wash:	3 CV 20 mM Tris, pH 8.0 + 400 mM NaCl
Elution buffer:	20 mM Tris, pH 8.0 + 550 mM NaCl
System:	ÄKTA pure 25

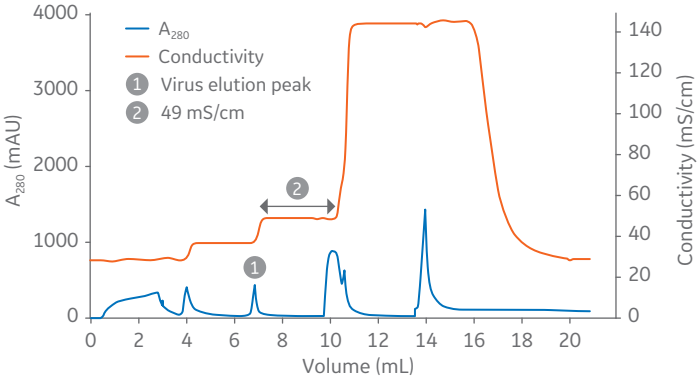


Fig 3. (A) Overlaid chromatograms from Capto Q and Capto Q ImpRes runs, employing linear elution gradient**.** As load volumes differed between the resins, the conductivity and UV curves for Capto Q were shifted to match the conductivity curve for Capto Q ImpRes to allow visualization of the different elution patterns. The markers indicate where the virus peak was eluted (blue for Capto Q and pink for Capto Q ImpRes). Chromatograms from using step elution gradient with (B) Capto Q ImpRes and (C) Capto Q resins.

Table 2. Results from capture step using selected resins

Resin	Elution method	Sample treatment	Total protein reduction (%)	Total DNA reduction (%)	hcDNA reduction (%)
Capto Q ImpRes	Linear gradient	TFF	99	92	96
Capto Q ImpRes	Step gradient	TFF	99	83	84
Capto Q	Linear gradient	TFF	99	99	100
Capto Q	Step gradient	TFF	99	98	96
ReadyToProcess Adsorber Q	Step gradient	TFF	86	77	84
ReadyToProcess Adsorber Q	Step gradient	NFF	95	80	NA

NA = not analyzed.

Adenovirus polishing step

An adenovirus polishing step was included in the purification process to further reduce impurities. For this step, both Capto Core 700 multimodal and Sepharose 4 Fast Flow SEC resins were evaluated. Capto Core 700 consists of an inert shell and a ligand-containing core, providing dual functionality to the resin. Pores in the shell allow small proteins and impurities to enter and be captured in the core, while the virus particles pass in the flowthrough (8).

Adenovirus recovery and purity were analyzed over the process steps. Sepharose 4 Fast Flow and Capto Core 700 resins offered a similar performance in terms of adenovirus purity, however, Capto Core 700 exhibited a clear advantage over Sepharose 4 Fast Flow in terms of sample load volume. Sample load for Capto Core 700 was up to 30 CV, whereas only 0.1 CV was loaded onto the Sepharose 4 Fast Flow column. Virus recovery was also determined to be higher for Capto Core 700, although high variability of the qPCR assay. The overall downstream process results for the smaller scale are summarized in Table 3.

Although Capto Q provided higher impurity reduction than Capto Q ImpRes, the results from evaluation of polishing resins show that Capto Core 700 reduced the remaining impurities in eluates from both resins to below limit of detection (LOD). As Capto Q ImpRes provided higher load capacity, supporting process economy improvements, Capto Q ImpRes was selected over Capto Q.

As observed during development of the capture step, eluate from ReadyToProcess Adsorber Q contained significantly higher amounts of both total protein and total DNA compared with eluates from Capto Q and Capto Q ImpRes resins due to the lower resolution between virus and impurities of the membrane. The larger amount of DNA in the ReadyToProcess Adsorber Q eluate was not completely cleared over the Capto Core 700 step, probably due to presence of large DNA fragments that were unable to enter the core of the bead. Therefore, Sepharose 4 Fast Flow was used for polishing when ReadyToProcess Adsorber Q was used in the capture step.

Table 3. Results from adenovirus polishing steps

Capture	Polishing	Load	Recovery of total virus particles (%)*	Total protein (µg/dose)	Total DNA (ng/dose)	hcDNA (ng/dose)
Capto Q ImpRes	Sepharose 4 Fast Flow	0.1 CV	39/57	< LOD	< LOD	< LOD
	Capto Core 700	26 CV	65/100	< LOD	< LOD	< LOD
Capto Q	Sepharose 4 Fast Flow	0.1 CV	57	< LOD	< LOD	< LOD
	Capto Core 700	18 CV	100/100	< LOD	< LOD	< LOD
ReadyToProcess Adsorber Q	Sepharose 4 Fast Flow	0.1 CV	66	< LOD	35	13
	Capto Core 700	30 CV	44†	< LOD	174	NA

*Total virus titer monitored by qPCR.

†Additional analysis of intact virus particles by HPLC showed an estimated recovery of 80% to 100%.

Two numbers indicate that the same sample was analyzed twice. NA = not analyzed.

Based on these results, two parallel processes were developed: Process 1 combining Capto Q ImpRes and Capto Core 700, and Process 2 combining Adsorber Q and Sepharose 4 Fast Flow (Fig 4).

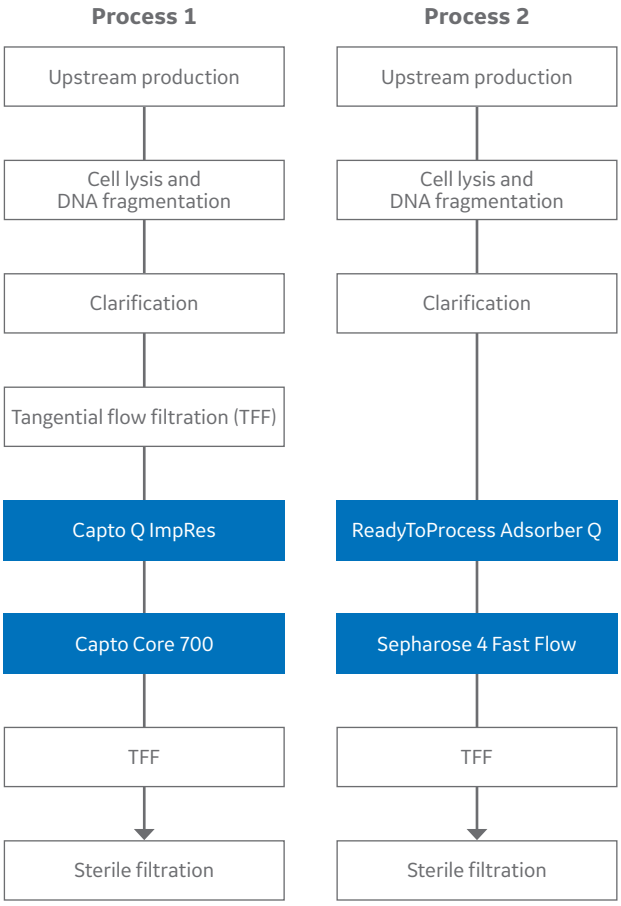


Fig 4. The developed two-step chromatography processes.

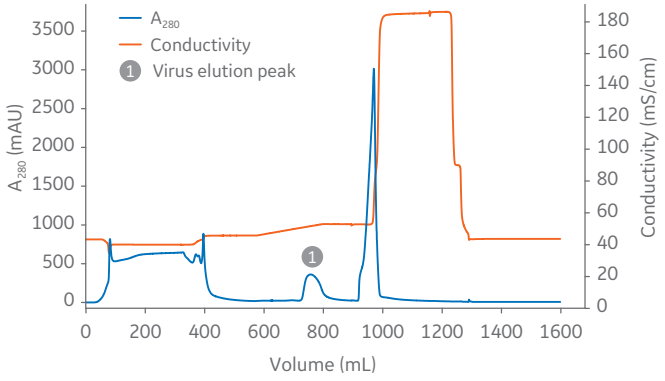
Scale-up adenovirus purification process

Processes 1 and 2 were scaled for purification of adenovirus from 3 L cell culture harvest. As opposed to the small-scale experiments, where Process 1 showed a clear advantage over Process 2 in terms of impurity reduction, the scaled-up experiments provided comparable results between the processes. In the scaled-up experiments, hcDNA levels in the final samples were similar. However, Process 1 reduced HCP levels to below LOD, whereas in Process 2, HCP levels in the final sample were 162 ng/mL in average. The amount of total virus particles in the final samples was comparable between the processes (Process 1: 4.9×10^{13} and 5.3×10^{13} vp; Process 2: 3.5×10^{13} and 4.4×10^{13} vp).

Chromatograms for Process 1 are shown in Figure 5, and chromatograms for Process 2 are shown in Figure 6. Results from the scaled-up processes are summarized in Table 4.

(A)

Sample:	Harvest subjected to NFF and TFF in 20 mM Tris, pH 8.0 + 450 mM NaCl
Resin:	Capto Q ImpRes
Column:	HiScale 26
Load:	5.6×10^{11} VP /mL resin (80% of Q_{B10}, 10 min residence time)
Binding buffer:	20 mM Tris, pH 8.0 + 450 mM NaCl, 2 mM $MgCl_2$
Wash:	2 CV 20 mM Tris, pH 8.0 + 480 mM NaCl, 2 mM $MgCl_2$
Elution buffer:	20 mM Tris, pH 8.0 + 450 to 570 mM NaCl in 2.5 CV, 2 mM $MgCl_2$
System:	ÄKTA pure 150



(B)

Sample:	Eluate from capture step
Resin:	Capto Core 700
Column:	HiScale 16
Load:	9 CV Capto Q ImpRes eluate
Binding buffer:	20 mM Tris, pH 8.0 + 500 mM NaCl, 2 mM $MgCl_2$
Wash:	1.5 CV of binding buffer
System:	ÄKTA pure 150

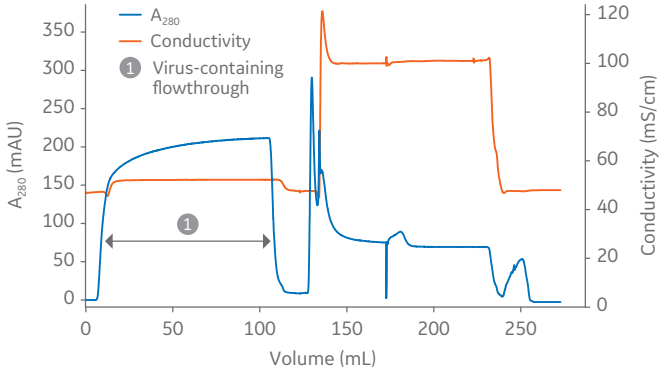


Fig 5. Chromatograms from scale-up of Process 1, using (A) Capto Q ImpRes for the capture step and (B) Capto Core 700 for the polishing step.

Table 4. Adenovirus recovery and purity in the developed processes

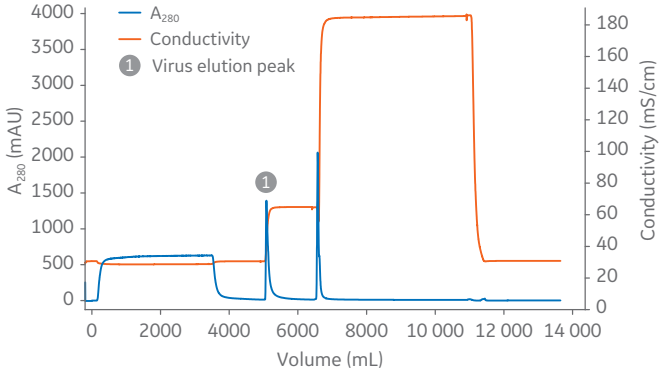
	Recovery of total virus protein (%)	Recovery of infectious virus particles (%)	HCP (ng/mL)	Total protein (µg/dose)	hcDNA (ng/dose)	Total DNA (ng/dose)
Process 1, Run 1	46/68	39	< LOD	13/11	< LOD	4/12
Process 1, Run 2*	17	40	< LOD	10	< LOD	20
Process 1 average	**37**	**40**	**< LOD**	**11**	**< LOD**	**14**
Process 2, Run 1	30/44	63	169	30/16	< LOD	17/8
Process 2, Run 2	41/50	28	155	20/3	< LOD	12/5
Process 2 average	**41**	**46**	**162**	**17**	**< LOD**	**11**

* Analysis only performed once.

Two numbers indicate that the same sample was analyzed twice.

(A)

Sample: Harvest subjected to NFF
Membrane: ReadyToProcess Adsorber Q
Capsule: 150 mL
Load: 8.9×10^{11} VP /mL resin (80% of Q_{B10}, 0.2 min residence time)
Binding buffer: 20 mM Tris, pH 8.0 + 300 mM NaCl, 2 mM $MgCl_2$
Wash: 10 MV of binding buffer
Elution buffer: 20 mM Tris, pH 8.0 + 720 mM NaCl, 2 mM $MgCl_2$
System: ÄKTA pure 150



(B)

Sample: Eluate from capture step
Resin: Sepharose 4 Fast Flow
Column: HiScale 50
Load: 0.2 CV
Buffer 1: 20 mM sodium phosphate, pH 7.3 + 200 mM NaCl, 2 mM $MgCl_2$, 2 % sucrose
System: ÄKTA pure 150

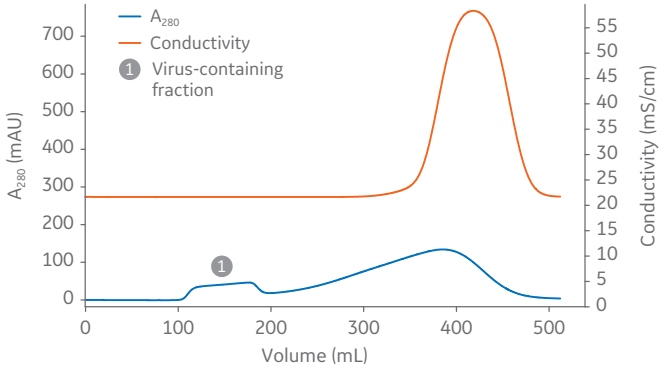


Fig 6. Chromatograms from scale-up of Process 2, using (A) ReadyToProcess Adsorber Q for the capture step and (B) Sepharose 4 Fast Flow for the polishing step.

Conclusion

Here, we describe the development of two downstream processes for purification of adenovirus from cell culture harvest: Process 1 using a combination of Capto Q ImpRes anion exchange resin and Capto Core 700 multimodal resin, and Process 2 using a combination of the ReadyToProcess Adsorber Q anion exchange membrane and Sepharose 4 Fast Flow SEC resin. The ReadyToProcess Adsorber Q membrane was found to exhibit higher binding capacity than the tested resins and its flow properties allowed omitting the TFF step. However, the separation of virus from impurities was not sufficient for the membrane and the eluted adenovirus was thus less pure than virus eluted from the Capto Q ImpRes resin. Of the investigated resins, Capto Q ImpRes, exhibited the highest binding capacity for adenovirus. In smaller scale, Process 1 showed a clear advantage with regard to impurity reduction. In the scale-up experiments, however, the difference between Processes 1 and 2 was less significant. The developed processes show similar performance, and are both viable options for purification of adenovirus.

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6. Application note: Adenovirus production in single-use ReadyToProcess WAVE 25 bioreactor system. GE Healthcare, KA879160418AN (2018).
7. Application note: Optimization of midstream cell lysis and virus filtration steps in an adenovirus purification process. GE Healthcare, KA875220218AN (2018).
8. Application note: Ovalbumin removal in egg-based influenza vaccine production using Capto Core 700. GE Healthcare, 29103762, Edition AA (2014).

Ordering information

Product	Description	Product code
ÄKTA Pure 25	Chromatography system	29018225
ÄKTA pure 150	Chromatography system	29046665
HiTrap Capto Q ImpRes	5 × 1 mL prepacked column	17547051
HiTrap Capto Q	5 × 1 mL prepacked column	11001302
HiTrap Q XL	5 × 1 mL prepacked column	17515801
HiTrap Q FF	5 × 1 mL prepacked column	17505301
HiTrap ANX FF	5 × 1 mL prepacked column	17516201
HiTrap DEAE FF	5 × 1 mL prepacked column	17505501
HiTrap Capto DEAE	5 × 1 mL prepacked column	28916537
HiTrap Capto adhere	5 × 1 mL prepacked column	28405844
HiTrap Capto adhere ImpRes	5 × 1 mL prepacked column	17371510
HiTrap Capto Core 700	5 × 1 mL prepacked column	17548151
ReadyToProcess Adsorber Q nano	4 mm membrane capsule	17372103
ReadyToProcess Adsorber Q 150	8 mm membrane capsule	17372113
Capto Q ImpRes	100 mL	17547002
Capto Core 700	25 mL	17548101
Sepharose 4 Fast Flow	1 L	17014901
Amersham QuickStain	1 kit	RPN4000
Amersham WB goat anti-rabbit Cy3	150 µg/vial	29038276
IN Cell Analyzer 2200	Cell imaging system	29027886

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